W. B. No. 870

U. S. DEPARTMENT OF AGRICULTURE
WEATHER BUREAU

MONTHLY WEATHER REVIEW

VOLUME 53, No. 5

MAY, 1925

WASHINGTON
GOVERNMENT PRINTING OFFICE
1925

MAY, 1925

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CORRECTION

REVIEW, April, 1925:

On page 180 (table of flood stages) footnote No. 2 should read: "Below flood stage at 8 a. m., April 1." Footnote No. 3 should read: "Continued at end of month."

† In marine separate.

MONTHLY WEATHER REVIEW

Editor, ALFRED J. HENRY. Assistant Editor, BURTON M. VARNEY.

VOL. 53, No. 5
W. B. No. 870

MAY, 1925

CLOSED JULY 3, 1925
ISSUED AUGUST 7, 1925

WEATHER FORECASTING AS AN AID IN PREVENTING AND CONTROLLING FOREST FIRES[1]

By E. B. CALVERT

[United States Weather Bureau, Washington, May, 1925]

The subject which has been assigned to me deals with a service rendered by the Weather Bureau with which the general public is only slightly acquainted. It is nevertheless one of great economic importance. It involves a number of more or less distinct phases, including the securing of meteorological and other observations, research on the basis of these, specialized forecasting, rapid and efficient communication facilities, and extensive cooperation with the Forest Service, State organizations and private forestry conservation associations.

It would require far too much time to attempt to cover the full range of the subject. Therefore, I will briefly sketch the history of the work, confining myself largely to developments in the practical side of it in the last few years.

The issuing of forecasts as an aid to the protection of forests against fires is not new. At first the regular daily forecasts were applied in the main incidentally by forestry interests in the Pacific coast States, but the advantages derived from utilizing them were so apparent that requests for a service more directly applicable to the particular purpose became very insistent, especially in the far Western States, and led to the organization of a distinctive forecast project, known as the fire-weather warning service.

The worst fires in Washington and Oregon occur in connection with the dreaded east wind. When these winds are preceded by a period of even ordinarily warm, dry weather, conditions are caused under which fires start easily; and when started, human effort, even when thoroughly organized, is taxed to the utmost in controling them. Frequently this is not accomplished until after vast areas have been devastated, many thousand dollars worth of timber destroyed, and lives sacrificed. The year 1910 was characterized by destructive forest fires in the North Pacific States, and there was a repetition in 1912. Therefore, in the spring of 1913 the Forest Service and the Western Forestry and Conservation Commission appealed to the Weather Bureau to make a special study of the meteorological conditions under which the east winds occur, with a view to forecasting them far enough in advance for preparations to be made to prevent fires by shutting down logging operations, by refraining from intentional burning of slash and débris, and by the taking of many other precautions familiar to protective agencies; also to enable the fire-fighting units to be put on guard and deployed in such way as to attack fires with the least possible delay.

The Weather Bureau was eager to render assistance to the fullest extent of its funds and facilities. However, this was by no means easy of accomplishment. No weather reports were available from certain large forested areas, especially from British Columbia. Reports from the latter region were especially important because the east winds of Washington and Oregon are caused by high-pressure areas moving across British Columbia to Alberta and Montana. Any attempt to issue fire-weather forecasts without the aid of telegraphic weather reports from British Columbia (it should be remembered that at that time observations from Alaska were not available) would indeed be a precarious undertaking. However, through the energetic interest of Sir Frederic Stupart, director of the Canadian Meteorological Service, an arrangement was made for obtaining twice-daily telegraphic weather reports from Prince Rupert, Barkerville, and Triangle Island, and by the time the season of fire hazard in 1914 arrived, a forecasting system for the States of Washington and Oregon, Idaho, and California was in operation. Forecasts for Washington and Oregon were issued by the district forecaster at Portland and for Idaho and California by the district forecaster at San Francisco. This was the beginning of what is now known as the fire-weather warning service, although it was not officially so designated until 1916.

It may interest you to know that the correspondence and negotiations in 1913 regarding organization of the service occurred in large part during the hiatus between the removal of the former chief of the Weather Bureau and the appointment of Professor Marvin to that post; and that when, shortly after his appointment, Doctor Marvin placed his indorsement on the papers approving the program for the Pacific Coast States, that indorsement contained the following significant statement:

> I think the Weather Bureau can render important service in the interest of the prevention of forest fires, and I believe the service could be extended to include any or all of the reservations more or less directly under the charge of the Forest Service, in the East as well as in the West.

The most important statement in this indorsement is that concerning extension of the work. It was not long before this was done. Under date of April 10, 1916, instructions were issued announcing the "fire-weather warnings" as a separate forecasting service. The historic importance of this announcement leads me to quote from it the following description of the scope of the service:

> District forecasters are authorized to issue warnings to be known as "fire-weather warnings" of conditions favorable for the inception and spread of fires in the forested regions of their respective districts. A careful study of these conditions, as comprehensive as practicable, especially of the wind directions as affected by the topography of the district, should be made by the district forecasters. In this study they will be assisted by the officials in charge of climatological sections, who will respond to any request for information in regard to their respective sections. Correspondence with the district foresters is also suggested in this connection.

[1] Presented before the American Meteorological Society, Washington, D. C., May 1, 1925.

Officials in charge of sections will advise the district forecasters each year as to the time when these warnings should begin and end, as determined by the condition of the timber and foliage. In the furtherance of this project stations of observation, to be equipped with such instruments as are necessary, may be established at favorable localities in the forest regions. Arrangements for the effective distribution of the warnings will be made by the officials in charge of climatological sections in cooperation with the interests to be served.

At the time these instructions were issued, officials of the Forest Service and the Weather Bureau were conferring as to a definite plan of cooperation for providing weather reports from forested areas and for determining those forests for which service was most urgent. As the details of these plans could not be completed for several months, the preliminary instructions just quoted from were issued, so that the district forecasters might render whatever service was required during the fire-hazard season then at hand. The details were completed during the summer, and on August 26, 1916, the preliminary instructions were amended, to give the names and locations of the most important forest areas subject to serious forest fires and other details. It is necessary to quote only that portion of these instructions which relates to the important features concerning the securing of weather observations from within the forests.

District forecasters will, by personal conference or by correspondence with the district forester in charge of the respective districts, endeavor to arrange for the establishment of a limited number of fire-weather warning stations, using Forest Service employees, in place as observers. The instrumental equipment of these stations will consist of an anemometer that has been fitted with a suitable device for readily obtaining the hourly velocity of the wind. Observations will be as simple as possible consistent with the needs of the service. A single daily observation of the direction and velocity of the wind, together with at least one daily dial reading of the anemometer will generally suffice.

I may say in passing that the "anemometer fitted with a suitable device for readily obtaining the hourly velocity of the wind" was devised by Mr. B. C. Kadel, chief of the instrument division of the Weather Bureau, especially for the fire-weather warning work. The purpose was to provide for inexperienced observers an instrument devoid of complicated dial readings and one that would not require the use of self-registering apparatus. The new anemometer was the now well-known "buzzer" type.

In the early summer of 1924 the conditions in the forests of California, Oregon, and Washington were unusually menacing, due to abnormal dryness, and the prospects were for a very serious fire season. In this emergency the Forest Service and forestry associations of Washington and Oregon, knowing that the Weather Bureau did not have the means for providing more service than in previous years, offered financial assistance if meteorologists were assigned to study conditions in these States and to issue localized forecasts and advices. The proposal was accepted, and meteorologists George W. Alexander and Charles I. Dague were withdrawn from other duties and assigned to the fire-weather work. Mr. Alexander was given headquarters at Seattle and charge of the work in Washington, while Mr. Dague made his headquarters at Portland and operated in Oregon. The California service was handled directly by Mr. E. H. Bowie, district forecaster at San Francisco. The cooperative arrangements provided that the salaries of the two meteorologists, telegraphic expense for weather observations from special stations located in the forests, and for the transmission of forecasts and advices to key distributing points should be borne by the Weather Bureau; and that traveling and subsistence expenses of the meteorologists while in the field, the providing of instruments at special stations, expenses incidental to the establishing and maintaining of these stations, and the distribution of the forecasts within the forests would be met by the forestry associations.

It was not possible for Messrs. Alexander and Dague to be relieved of their regular station assignments until midsummer. Arriving at their headquarters about the middle of July, 1924, they proceeded at once to organize an intensive preliminary survey of the meteorological conditions in their respective forest areas. It seemed best for forecasting purposes to divide the States into districts and subdivisions determined by forest types, topography, etc. Thus in the State of Washington two major divisions were decided on—eastern and western—and these in turn were subdivided into three and four sections, respectively. The subdivisions had more or less definite geographic bounds and were given identifying numbers which were used in the forecast messages for convenience and economy in distribution.

The instrumental equipment usually provided for cooperative stations was used at each of the substations, and in addition, sling psychrometers and anemometers were provided at some of them. The purpose was to obtain as extensive a survey of humidity conditions in the forests as was possible in the hurried circumstances under which the work was begun. Daily observations were telegraphed or telephoned from the substations to the headquarters. These reports, in conjunction with the extensive system of observations received over circuits from regular stations in the United States and Canada, were very helpful in the preparation of forecasts and advices.

The first of the fire-weather forecasts under the new arrangement was issued from Seattle on August 1, 1924, and about the same time from Portland. They were continued daily until the middle of October, when the season of fire-hazard ended.

The apprehension early in that year regarding a disastrous forest-fire season in the Western States was fully justified. In California the number of fires, the area burned over and the damage done exceeded that of any other year and the fires in Washington and Oregon were exceptionally disastrous. The following comment appeared in a Forest Service news letter under date of October 31, 1924:

The most disastrous fire season that has occurred in California in a decade was closed this month by timely fall rains. Two years of markedly deficient rainfall was the outstanding factor which brought about this critical condition. The 1924 fire record surpassed in number of fires and total area burned that of 1917, a record fire year, also one of the driest seasons ever experienced in the State.

During the period January 1 to October 20, there were 2,439 forest, brush, and grain fires in California which burned over 827,000 acres, an area greater than the State of Rhode Island, and caused an estimated loss of over $5,000,000 worth of natural resources and improved property. Thirty-two per cent of all fires were caused by lightning, and 68 per cent were due to careless acts of man. Of the man-caused fires, 38 per cent were traced to smokers, largely users of "tailor-made" cigarettes, and campers were responsible for 13 per cent, incendiaries 14 per cent, brush burners 8 per cent, railroads 6 per cent, lumbering operations 4 per cent, and miscellaneous causes 17 per cent.

Out of the total of 2,439 fires, 1,890 were within or adjacent to national forests and 549 were on State or private lands. Government land burned over amounted to 365,332 acres, or less than 2 per cent of the national forest area of the State. Private and State lands burned totaled 461,668 acres. The United States Forest Service spent $920,000 on fire suppression during the season.

Outstanding features of the 1924 fire season were: Four fire fighters killed on the fire line; the occurrence of over 100 large

fires ranging from 2,000 to more than 50,000 acres in area; the closure to public use of 10,000,000 acres of national forest land, and restrictions on camping and smoking placed on several million additional acres.

It will be noted that lightning was responsible for a large percentage of the fires. Attention is invited to this fact because it is well known to the forecasters that lightning is a large factor in forest-fire causation in the Pacific Coast States. They are alert to issue warnings whenever meteorological conditions indicate the probability of thunderstorms. Such advices obviously are very important.

Humidity also is now recognized as being of special significance in connection with the starting and spread of forest fires. It is being studied perhaps more intensively than any other factor connected with the problem. Last year humidity data were included in the reports telegraphed from regular Weather Bureau stations in the far Western States and in the reports from special stations. The warning messages nearly always contained forecasts, in general terms, of expected humidity conditions. This aspect of the subject is far too extensive to be more than mentioned here. Those interested will find in the MONTHLY WEATHER REVIEW several articles relating thereto.

The accomplishment of the Weather Bureau officials in the Pacific Coast States last year (the first time that expert meteorologists were ever assigned specifically and exclusively to the problem), notwithstanding that the program had to be organized and carried out in a hurry, is best shown by quotations from officials of the forestry associations whose financial contributions made the work possible:

Mr. George C. Joy, chief fire warden, Washington Forest Fires Association, October 9, 1924:

> The forecasts were timely and accurate, and this information was of the greatest assistance to all forest agencies and logging operators in preventing fires.
>
> Upon receipt of a forecast we passed it on to our field men and to loggers, with the result that extra precautions were immediately taken to prevent fires being started. It also enabled those desiring to burn slashings to choose the most opportune time to do so. Several fires were averted through our advising owners of slashings that bad fire weather was impending and for them not to burn. In these particulars the forecasts have been of direct and specific value to all forest interests. In addition, it has aroused the interest of people generally in fire prevention, and especially has this been the case with the personnel of the forest protective agencies.
>
> We are satisfied with what has already been accomplished and feel that the money we have put into the undertaking has bought us more protection than from any other particular item of our expenditures.
>
> We think that this phase of Weather Bureau activities is of the greatest moment to forest protection, and is an aid in furthering and expediting reforestation, and we earnestly urge that the investigative work you have begun this season be continued and made permanent.

Mr. C. C. Scott, secretary, County Fire Patrol Association, October 6, 1924:

> Now that our fire season is definitely over, I want to write you briefly expressing our appreciation of the most excellent service you have rendered the fire protection agencies, and to give you some idea of how the forecasts have been received by wardens and operators in the woods.
>
> As you know, at the beginning of the season many operators and some few wardens were skeptical as to the benefit to be derived from these forecasts. In other words, their education along fire-weather lines as it applied to burning conditions had been neglected. From this season's experience I know I am safe in saying that 100 per cent of our wardens and 80 per cent of the operators in our district are absolutely sold on the fire-weather forecast.
>
> Your forecasts have been remarkably accurate. Considering the rather limited facilities for gathering your information, I don't see how you do it. A practical illustration of how the forecast works is as follows:
>
> Early on the morning of September 12 you sent me fire warning. I immediately got busy on the phone, calling wardens and operators. One operator was advised to shut down his camp or double or treble his protection organization around operation. Just after I called him at his Portland office our local warden called his camp direct and gave practically the same advice I had given the Portland office. Our advice was not acted upon and as a result fire broke out in the operation that afternoon which eventually cost $60,000 in loss of logs, equipment, and time. This operator now believes 100 per cent in fire weather forecasts.
>
> Many operators, however, have called regularly in regard to weather and have shut down their camps each time the warden has advised them of the approach of bad fire weather. The idea of special fire-weather forecasts, being a new thing, had first to be sold to the operator. I believe that our work along this line this year has been so successful that next year the operators will all be anxious to get the forecasts and when the warden advises a shut down on account of fire weather their camps will be closed tight.
>
> As far as the associations which I represent are concerned, we want this service continued next year and will do everything in our power to bring about such a continuance.

It is impracticable to go into details regarding the service, the character of the observations, the location of substations, etc. Naturally, experience indicated the advisability of certain changes if the work were continued the following season. It was hoped that appropriations might be secured to enable the Weather Bureau to place the project on a permanent basis and to provide more adequately for improvement and development. Additional funds were not secured, but the forestry associations were unwilling to allow the work to lapse. They are again providing funds whereby the work may go ahead this year under practically the same conditions as last year, with the exception of minor changes. The work this year (1925) began on April 20 and will be continued into the month of October, or until the fire danger is past.

May I now call your attention, briefly, to the similar, though less highly specialized, service rendered by our Bureau in other parts of the country.

Since 1916 forecasts have been issued each year in the interest of protection of forests, especially in Montana, Minnesota, Michigan, Colorado, and Arkansas, by the appropriate district forecasters. They are issued only during periods when the district forecasters are notified by the fire wardens that the advices are needed. Although there have been some extensions each year and a considerable increase in the number of fire wardens to whom the forecasts are furnished, the work in these States is practically on the same basis as when it began. No meteorological surveys of the forests have been made by the Weather Bureau nor have any specific studies been undertaken. In phrase and substance these fire-weather forecasts and warnings are somewhat different from the ordinary daily weather forecasts and are made applicable to the conditions existing in the specific forest areas.

Prior to 1924 very little was done in the way of issuing regularly fire-weather forecasts in the eastern and southern States comprised within the Washington forecast district, although special forecasts had been made on numerous emergency occasions. In 1924 the first organized fire-weather warning service in the Eastern States was begun in Connecticut, in cooperation with the State forest fire warden. The warnings, which include indications of expected humidity, are prepared by Mr. L. M. Tarr, in charge of the Weather Bureau office at New Haven, and are issued only when more or less prolonged periods of dry weather are indicated. They are published on the weather map issued at that station, given distribution by the Associated Press and tele-

phoned or telegraphed to a limited number of wardens who further distribute them in the threatened areas.

As a result of the accomplishments in Connecticut and the Pacific Coast States, Mr. S. T. Dana, in charge of the Northeastern Forest Experiment Station (Forest Service) at Amherst, Mass., and Mr. E. N. Munns, chief of forest investigations of the Forest Service, urged that service be extended to include the remainder of the New England States and the Adirondack section of northern New York. They recognized that the Weather Bureau could not take on this extension of its work with existing appropriations, but the Chief of Bureau agreed to inaugurate a limited service if the forestry agencies of the various States would establish meteorological stations in the forests, make telegraphic reports therefrom available for use in the forecast work, and would assume at least a portion of the expense of disseminating the forecasts to the fire wardens and patrols. This offer was accepted. The various States concerned have established some of the required substations, and others will be in operation by May 15, 1925.

The forecasts and warnings for forests in Connecticut will continue to be issued at New Haven, those for the remainder of New England from Boston, and the forecasts for the Adirondack region from Albany.

The periods during which fire hazards usually occur in New England and the Adirondacks vary materially. Therefore for forecasting purposes these areas have been divided into sections according to the fire-hazard periods. The forecasts are couched in terms designed to be as helpful as possible to the wardens in appraising the fire hazard, and in this respect they follow very closely the plan of the harvest-weather forecasts as explained in the paper on that subject published in the February, 1925, issue of the MONTHLY WEATHER REVIEW. This plan is an innovation in so far as fire-weather warnings are concerned and is intended not only to accomplish an easy understanding of the scope and meaning of the forecasts, but to indicate the degree of the forecaster's confidence in the predictions. Special attention is given to forecasts of temperature, precipitation, wind direction and force, and thunderstorms. Thunderstorm forecasts, however, will be important only as they apply to the likelihood of precipitation and scattered showers, because lightning as a cause of forest fires in New England and northern New York is a negligible factor.

Humidity may be an item of importance in evaluating fire hazards in these regions, but humidity data are so deficient that no attempt will be made to forecast this element until reliable records of sufficient quantity have been obtained. Such records are being made at all the substations and it is hoped that enough will be secured this year to warrant an analysis of them which will justify an extension of the forecasts next year to include expected relative humidity changes.

A feature of the plan is that wardens and rangers at selected places in the forests are supplied with cards on which reports are made of the character of the weather each day and the moisture condition of the forest cover. These reports are expected to be of much aid to the forecasters as a check against their forecasts, and also a basis for research looking toward improvements in the service.

Regarding the Southern States, the situation is as follows: In March of this year (1925) the Weather Bureau received a resolution passed by the Appalachian Forest Research Council at its meeting February 13, 1925, at Asheville, N. C., urging "the development of a forest fire-weather prediction service adequate to meet the needs of the Appalachian forest region and to cooperate with the forest experiment station in the forest-fire studies conducted by the station." This council, composed of representatives of State experiment stations, forestry officials, forestry associations, and large lumbering corporations, is organized to coordinate and assist in investigations and service leading to forest conservation and to the development of the timber industry in the southern Appalachian region.

Lack of funds would not admit of the organization of a fire-weather warning service for the southern Appalachian region like that conducted in the Western States or even on the less extensive scale provided for New England and northern New York; but arrangements have been made whereby each morning during periods when fire hazard exists, a representative of the Forest Service secures from the forecaster in Washington by telephone, forecasts and advices concerning the probable weather conditions for various sections of the region in question. These forecasts are then telegraphed to the fire wardens, as circumstances warrant, without expense to the Weather Bureau. By this plan an expert forester, who is well informed regarding the topography and conditions in the areas for which the forecasts are made, has the advantage of personal discussion with the forecaster. Experience will probably show that more satisfactory service and more definite instructions to the fire wardens can be given in this way than by having the wardens depend on their own interpretations of necessarily brief forecasts sent directly to them.

Cards are furnished to fire wardens in the southern Appalachian region on which they make reports of daily weather, condition of forest cover, etc., for the same purpose as that referred to in respect to the New England and northern New York services.

Forest fires occur infrequently in the Appalachian region during the winter. The periods of greatest hazard are in the spring and late fall months. The fires in the spring depend chiefly on dry leaf fuel, which causes them to spread to other combustible fuels. Few fires occur after the new vegetation develops sufficiently to check the drying of the floor cover, but they begin again in the fall when the summer vegetation and the fallen leaves become dry. The hazard continues until it is removed by fall rains or snow.

Officials of the Weather Bureau who are connected with this work realize only too well the lack of sufficient knowledge concerning many factors in the relation between weather influences and forest fires, such as the indefinite but apparently important part that humidity plays in favoring the inception of fires, and in the rapidity of their spread. They know that weather forecasting in the aid of forest conservation can not be accomplished to its fullest degree without thorough scientific investigation of the subject in all its aspects. The bureau has never had funds which could be devoted to such investigations. Repeated efforts have been made to secure them, but thus far without success. However, the forecast work that has been done, practically without additional expenditures, and under discouraging handicaps, has proved the worth of the service, has elicited the commendation of forestry interests and in some instances has actuated State and private organizations to provide funds in order that the Weather Bureau might better function in their behalf. I am optimistic that in the near future the economic value of a service which gives in a single year, or in preventing a single fire, for that matter, a return of many thousand per cent, will become so patent that funds will be made available by which the great possibilities of the fire-weather warning service may be given at least a fair chance of attainment.

THE WARM FEBRUARY OF 1925 IN THE UNITED STATES

ALFRED J. HENRY

[Dated March 31, 1925]

February, 1925, in continental United States was the warmest February during the last 40 odd years. It has been warmer in individual districts in other years, but considering the country as a single geographic unit no other February has averaged as much as 5.8° F. above the normal for the country as a whole. The monthly departures ranged from a minimum of 1.2° above in the Florida peninsula to 10.1° above in the region embraced by the States of Montana, Wyoming, and the western parts of South Dakota and Nebraska. Chart III of the February REVIEW shows the geographical distribution of the monthly departures.

Attempt is made in what follows to correlate this pronounced temperature abnormality with atmospheric pressure and movement of cyclones and anticyclones.[1]

One naturally looks to the pressure distribution over the eastern North Pacific and Alaska as offering a first approximation to the cause of the temperature departure. The Northern Hemisphere twice-daily weather charts, although still far from complete, give some idea of the pressure distribution of the month. The outstanding pressure formations of the northeastern Pacific are the so-called North Pacific HIGH and the Aleutian LOW. Assuming that the average geographic position of the former in winter is longitude 140° W., latitude 35° N., and scaling from the morning Northern Hemisphere daily weather charts the daily pressures at the intersection of the two coordinates above given, I find that for December, 1924, average pressure in the center of the North Pacific HIGH was 0.06 inch below normal, for January, 1925, slightly above normal (+0.03), and that for the first half of January it was 0.33 inch higher than for the last half. The average for February determined in the same way was but 29.98 inches, or 0.22 inch below normal, therefore, pressure in the region occupied by the North Pacific HIGH was lower than usual from the middle of January to the end of February, 1925.

Statistical investigations of the relation between the pressure at Honolulu and over the Aleutians show that there is a sort of seesaw between the pressure of the two regions; that is, when pressure at Honolulu is low, pressure at the Aleutians is high, and vice versa. This relation seems, however, to be less pronounced than the similar one between the Azores and Iceland, partly because Honolulu pressures represent conditions on the extreme southwestern margin of the North Pacific HIGH, and perhaps to some extent also because the data are still somewhat scanty.

Pressure at Dutch Harbor in the Aleutians, also in interior Alaska and the Canadian Northwest in February, 1925, was also below the normal, so that we have to do with a widespread and pronounced departure of pressure below the normal.

How are we to interpret this phenomenon in terms of the weather in continental United States? Low pressure in Alaska and the Canadian Northwest is a condition favorable to the movement inland of cyclonic systems having their origin over the Pacific and, as we shall point out later, the many cyclones passing eastward along the northern border induce almost continuous southerly winds and consequently relatively high temperature. Now, if concurrently with the above the pressure over eastern United States and the western portion of the North Atlantic should be above the normal the flow of southerly winds will be intensified and the magnitude of the departure from normal will be increased.

Cyclones.—Reference to Chart II, Tracks of Centers of Cyclones, in the February, 1925, REVIEW, will show that while a relatively large number of cyclones has been plotted as originating over the Pacific, but a single one succeeded in crossing the continent.

The number of secondary cyclones that developed in February over the eastern Rocky Mountain slopes was considerably greater than usual, a circumstance probably closely related to the pressure distribution over the northeastern Pacific. On the whole, both primary and secondary cyclones of the month lacked in intensity and naturally strong pressure gradients were absent.

Anticyclones.—Tracks of anticyclones for February, 1915, are shown in the REVIEW for that month, Chart I. A fairly large proportion of these came in from the Pacific evidently being offshoots from the North Pacific HIGH and consequently were not associated with an indraught of cold air. The few anticyclones that came down from the Canadian Northwest likewise were not associated with the low temperatures characteristic of midwinter; thus we conclude that the cause of the exceptionally warm weather of February is explainable only when we clearly understand the reason for the weak pressure gradients of the month for northerly winds. If, instead of relatively high temperature in Alaska, the temperature had been low, a greater flow of polar air to the southward might have been expected.

This is equivalent to saying that in the final analysis the cause of pronounced abnormalities in the weather must be referred to the day-to-day movement of cyclones and anticyclones both in time and space. The latter will be considered more in detail in the concluding part of this paper.

It is only within the last year or so that weather charts for the Northern Hemisphere have become available, even in skeleton form. The network of vessel-reporting stations is as yet far too open-meshed to afford an accurate picture of the pressure distribution over the vast area of the Pacific, moreover, ships will continue to ply the oceans in the most direct sailing routes between the West and the East and vice versa. Thus reports from the remote and less traveled routes can hardly be expected, although reports from these regions are just as necessary to the meteorologist as those along great circle sailing routes.

At present weather reports are lacking for the region near and along the Arctic Circle from about 60° to 160° E., or a little more than one-quarter of the circumference of the globe. Weather reports from the remainder of high latitude areas are sufficient to picture in a general way that in winter a chain of cyclonic storms encircles at least three-fourths of the globe between the Arctic Circle as the northern limit and the belt of high pressure which spans the globe about 35° N. latitude.

It is to the latitudinal range in the path of cyclones and anticyclones that the variations in the weather of the greater part of the Northern Hemisphere are probably due. I say "probably" because no one has as yet shown that any other single element or combination of elements, whether of terrestrial or cosmical origin, has an influence as pronounced as that mentioned.

[1] These terms "cyclone and anticyclone" are synonymous with the familiar words "low and high" of the daily weather chart and are so used throughout this paper.

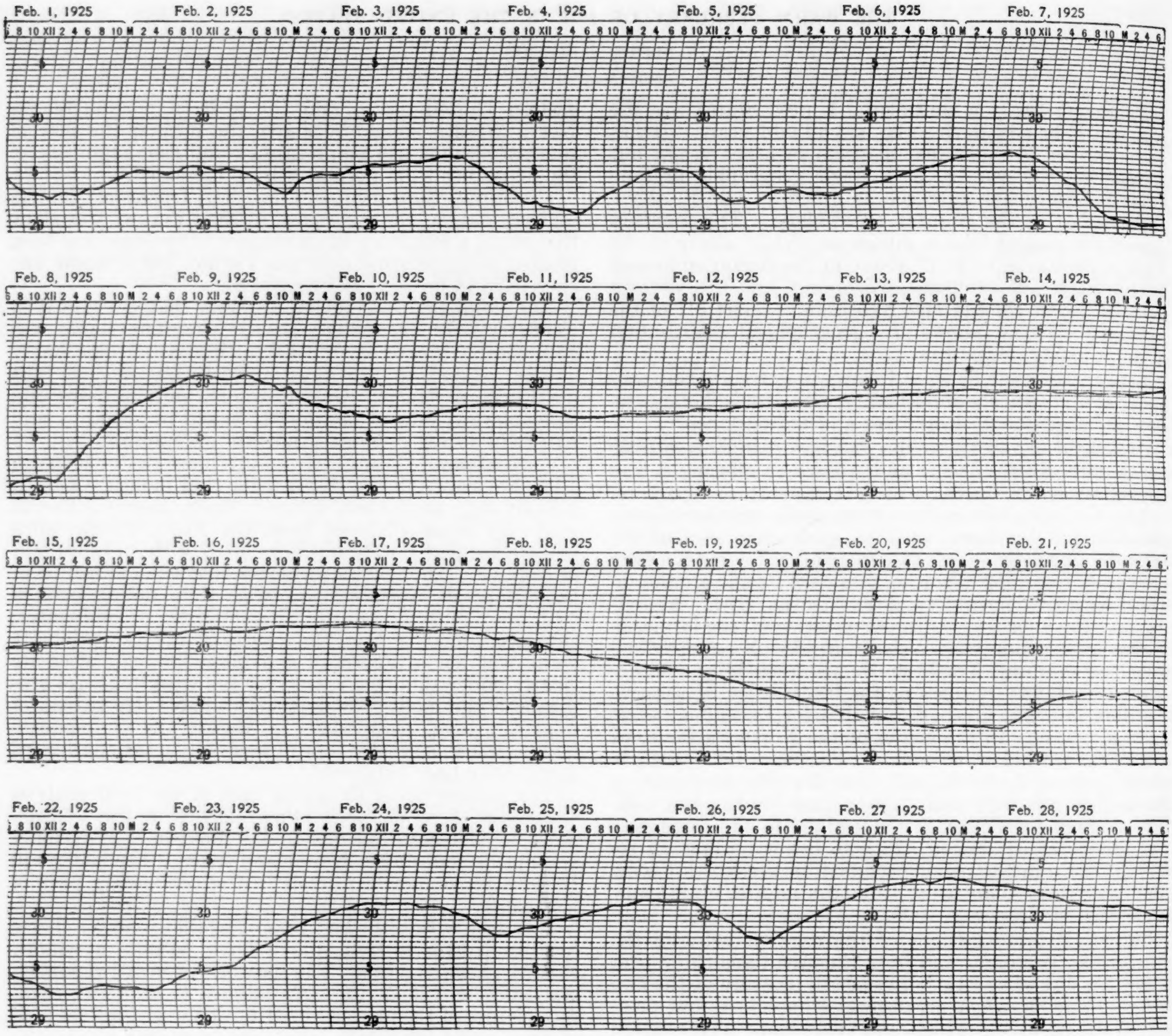

FIG. 1.—Barograms, Tatoosh Island, February, 1925

Whether in the years to come it will be possible to accurately delimit the movement of cyclones and anticyclones in latitude is still a debatable question.

Many references have appeared in the literature of long-range weather forecasting as to the control on the weather exerted by the so-called "centers of action," one of which, the North Pacific HIGH, comes within the purview of our inquiry. As previously stated, average pressure in that high during the last half of January and throughout February, 1925, was significantly below normal. Assuming that the published normal of 30.20 inches for the region in question is correct, a comparison of the daily February pressures with the normal shows that during February there were but 2 days with normal or above normal pressure, and, of course, 26 days with pressure below normal. The pressure in this region sank as low as 29.60 inches on the 9th–10th, when a cyclone of moderate intensity was centered in longitude 135° W., latitude 35° N. There was therefore a complete reversal of the normal pressure distribution for this particular part of the ocean.

What effect, if any, did this reversal have upon the weather of continental United States? The only direct influence so far as can be seen is the fact that the cyclone above mentioned greatly diminished in intensity, passed inland over California on the 11th, pursued a somewhat devious course, and disappeared over the Southern Plateau on the 13th.

On the dates of the reversal before mentioned the North Pacific HIGH was divided into two portions, an eastern one lying over the western United States and a western one over the ocean in longitude 160° to 170° W. As soon as the cyclone had passed over the continent pressure conditions over the ocean reverted to normal; hence the effect on the weather of the United States was only temporary.

It is difficult to consider the day-to-day fluctuations in pressure in the aggregate for a month or longer; I have

therefore drawn and present the barograph curves of Tatoosh Island—a prominent oceanic outlook station off the extreme northwest tip of the State of Washington—for the month of February, 1925. (See Fig. 1.)

The month has been divided into three portions, first, from February 1 to 10, when pressure rose and fell in a sort of cycle of one to two days in length, the hollows in the curves representing times when cyclonic storms approached the coast and the crests days when anticyclones were experienced.

The second period, viz, from the 10th to the 20th, was characterized by a slow but uniform increase in pressure to a crest about the 16th or 17th, when a more rapid fall to another cyclonic or storm period set in on the 20th and continued until the close of the month.

A verbal statement of the weather experienced during these three periods would not only be tedious but would also fail to convey an accurate image of what occurred; hence several series of weather maps will be presented to indicate the pressure formations which gave character to the weather experienced during the periods.

Northern Hemisphere weather charts.—The first series embraces the morning charts for February 1–4. To avoid congestion, the isobars on these charts for pressures below 30 inches have been drawn for intervals of three-tenths of an inch instead of one-tenth, as usual. In this and other series the peculiar trend of the isobars of a Pacific cyclone when approaching and passing onto the continent is clearly shown.

There is a resemblance between the charts here presented and that one drawn by Guldberg and Mohn on theoretical grounds in their well-known discussion of the movements of the atmosphere when a cyclone lies partly over land and partly over water.[2]

First indications of development of cyclones over land.—When the front of a Pacific cyclone of winter crosses the coast line, the isobars are systematically bent or bowed toward the southeast, never or rarely ever toward the northeast or north.

There is reason for thinking that the inflection toward the southeast is dependent on air column temperatures on the leeward side of mountain ranges that trend north-south over western North America. Since cyclones very frequently develop in the rear of eastward moving anticyclones a region of southerly and hence warm winds and also since, on occasion, high air temperatures (relatively) may result from compression in the descent of winds to the lower levels on the eastern or lee side of the mountains, that side must be a favorable location for the development of secondary disturbances. Eastern Colorado is such a location.

In a large number of cases a cyclone over the continent does not immediately develop as an oceanic cyclone approaches the coast, but in the ensuing 24 to 36 hours a low pressure area without well-developed cyclonic wind circulation generally appears either over the Plateau region or directly east of the main range of the Rocky Mountains; thus, reverting to Figure 2 and the chart for February 1, it will be noted that the isobar of 30 inches curves sharply to the southeast over British Columbia and northern Montana. This inflection becomes more pronounced on the succeeding charts of the 2d and 3d and finally on the chart for the 4th a separate cyclone is shown, while the original remains practically in its position over the Aleutians.

[2] Guldberg and Mohn in Mechanics of the Atmosphere, C. Abbe's 3d collection of translations, p. 233.

An examination of the April, 1925, Northern Hemisphere weather charts leads to the belief that the development of cyclones in the rear of an eastward moving anticyclone is more common than was at first thought. Very briefly described the situation in the beginning is as follows: The North Pacific anticyclone is close inshore and the companion continental anticyclone is likewise near the western shore line of the continent. Offshoots from these anticyclones are given off from time to time and move in a southeasterly direction; as soon as they gain distance to the eastward a trough or lane of low pressure is established between the two anticyclones. This trough serves as a channel along which offshoots from the Aleutian LOW advance over the continent. The channel may be closed at any place between latitude 40 and 60 N. by rising pressure which seems to advance from both the interior and the oceanic anticyclonic areas. Sometimes, but not often, the two anticyclones merge and remain merged for several days. At such times very cold weather prevails over the continent.

The closure rarely endures more than a day or so. The opening of the channel is brought about by falling pressure that is associated with cyclones which advance eastward over the Aleutians or the Gulf of Alaska, in connection with the east-southeast drift of the interior anticyclone.

Attention is directed to the southward looping of the isobar of 29.7 inches surrounding the Aleutian LOW of the 4th and to the fact that this looping may be taken as an indication that a secondary cyclone will be given off over the Canadian Northwest, as actually occurred on the 5th. Thus two secondaries one on the 4th, one on the 5th and yet a third was given off or developed over Montana on the p. m. of the 6th.

An intense North Pacific cyclone.—The second series of charts begins with the p. m. chart of the 7th and this is followed by the a. m. chart of the 8th, 9th, and 10th, respectively. This series shows something of the wind circulation in an intense North Pacific cyclone as it approaches the shore of the continent. Note for example the winds of hurricane force blowing in the rear half of the storm figured in the charts p. m. 7th and a. m. 8th. On the land side the winds were gentle to fresh; in the valleys and sheltered positions the velocity on the morning of the 8th was less than 10 m. p. h. and naturally the direction in these cases was controlled by local topography rather than by the barometric gradient.

The a. m. chart of the 8th presents an unusually interesting situation. One can not help wondering what becomes of the winds of hurricane force over the ocean in the left half of the cyclone. Evidently they do not curve around the center as in a true tropical cyclone since the maximum wind velocity for the date in question was but 64 m. p. h. at an exposed point on the Washington coast.

It may be that the unbalanced system of forces in the vortex operates to destroy it, in any event the examination of a number of cases leads to the conclusion that the intensity of winter cyclones of the northeast Pacific diminishes rapidly as the cyclones impinge upon the coast.

Prof. T. Terada of the Imperial Univeristy of Tokyo has shown statistically[3] that the cyclones of the Far East have a tendency to pass over land in summer, while they move over water, avoiding land in winter.

[3] Quoted by T. Kobayasi in Quarterly Jour. Loyal Met. Soc. 48: 169.

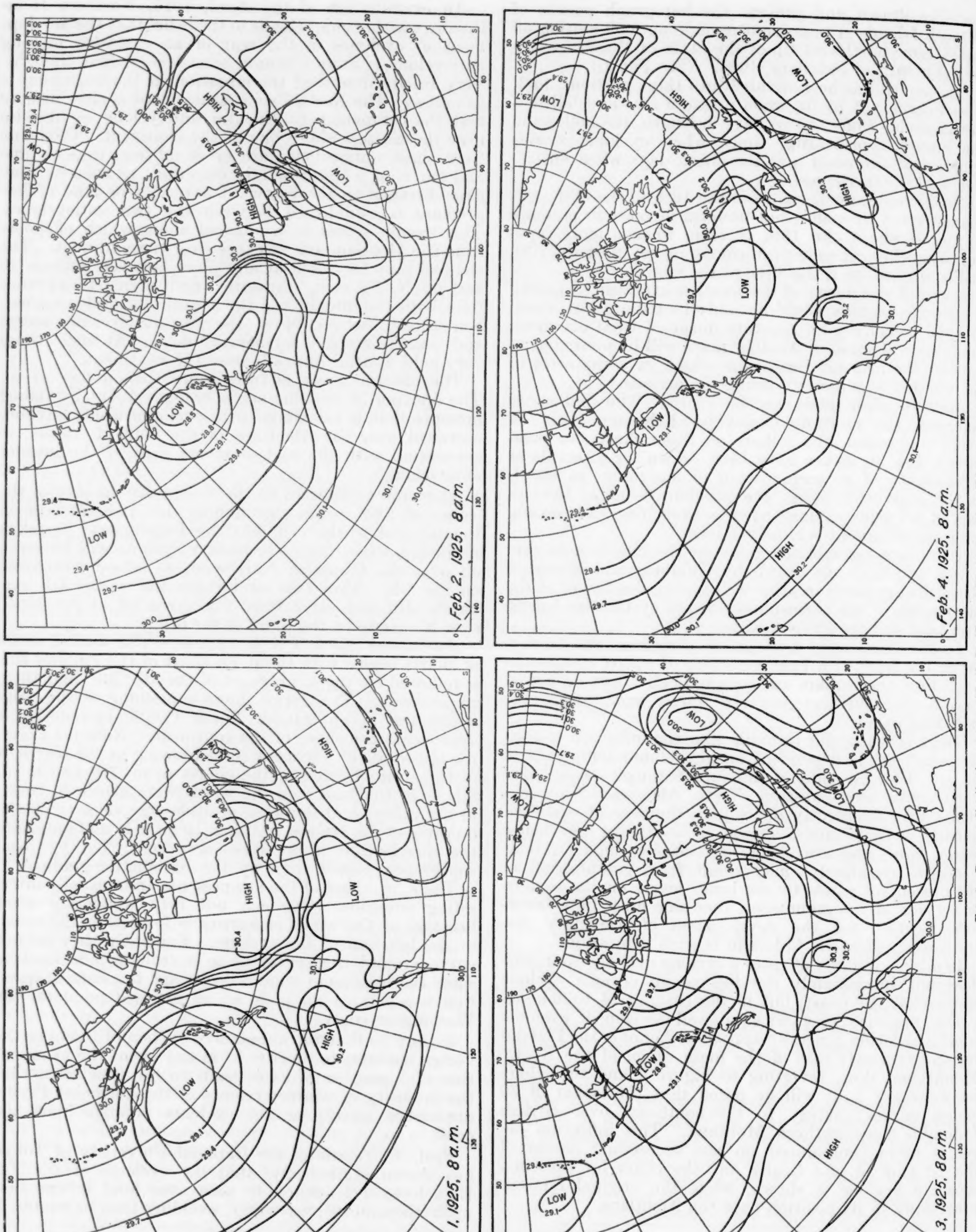

FIG. 2.—Pressure distribution, eastern North Pacific and North America, February 1-4, 1925

The charts of the 9th and 10th present very interesting transformations. The great cyclone of the 8th, or what was left of it, was centered about longitude 138° W., latitude 42° N., where it had apparently severed the North Pacific HIGH into two parts as shown on the above-named charts.

The period February 10–20.—Reference to Figure 1 will show that after a rise in pressure at Tatoosh Island on the 9th, pressure then fell slightly as the cyclone mentioned in the preceding paragraph passed inland; it then rose rather slowly but uniformly to a crest on the 16th–17th, then fell to the minimum of the 20th. During this time cyclones did not come in from the Pacific; however, three, all of continental origin, gave to the weather east of the 100th meridian the character it possessed. The first of the three developed over the Province of Alberta, directly in the rear of an eastward moving anticyclone. The remaining two developed over eastern Colorado, moved thence to Oklahoma, recurved to the northeast, and eventually passed off to sea over the Atlantic. During this time three weak anticyclones came from Canada and while temperature was lowered for a short time it almost immediately regained its former high level.

The final period, February 20–28.—This period was characterized by rather frequent but not pronounced storm movement. As early as the 19th the isobar of 29.90 inches of a great oceanic cyclone had extended southeastward over the continent almost to the Mississippi River, thus forming a great loop or tongue of low pressure without pronounced cyclonic circulation over the western third of the country. Twenty-four hours later this low pressure had spread eastward so that it extended from the lower Ohio Valley to the Gulf of Alaska and this region of low pressure was flanked on the northeast and southwest by regions of higher pressure.

The Northern Hemisphere charts, p. m. 23d to a. m. 26th, not including those of the 26th, are reproduced as Figure 4.

These charts illustrate the transformations by which a fully-developed cyclone is at times formed within a great area of low pressure partly over land and partly over water.

The chart, p. m. 23d, shows a series of four cyclones in tandem, so to speak, the eastern one being centered over Atlantic Coast States. This cyclone is separated from those to the westward by a shallow ridge of higher pressure that extends from the Gulf of Mexico northward to the Lake region, where pressure is slightly below 30 inches. Ordinarily the temperature in the rear of a winter cyclone falls considerably, but in this case perhaps by reason of the close approach of a second cyclone with its system of southerly winds on the eastern margin, marked changes to lower temperature did not occur.

The p. m. chart of the 23d shows the presence of a pressure formation known to meteorologists as a "saddle"—a region of nearly uniform pressure between two adjoining HIGHS. Such a formation in this instance indicated that the eastern cyclone, or LOW, would be cut off from its connection with the oceanic low by way of the "saddle." Subsequent charts show that this was accomplished and thus an independent cyclone was set in motion.

This cyclone greatly increased in intensity as it passed down the St. Lawrence Valley. On the morning of the 27th central pressure in it had fallen to 28.95 inches at the mouth of the St. Lawrence and the gradient for northerly winds in its rear on that and the following day was much stronger than on any previous day of the month. Thus it is apparent that in the final analysie the degree of cold experienced in the several parts of ths country is conditioned very largely upon the depths to which pressure at the center of cyclonic systems falls, which in turn determines the barometric gradients and the flow of polar air equatorward.

The concluding chart of this series, February 26 (a. m.), shows the beginning of a fresh intrusion of a Pacific cyclone; it also shows the isobars of the cyclone that was centered over the mouth of the St. Lawrence that was considered in the preceding paragraph.

III. CORRELATION BETWEEN PRESSURES IN DISTANT REGIONS

Sir Gilbert Walker in his studies of world weather relations has determined and published correlation coefficients [4] between the so-called "centers of action." Among these are Honolulu, as representative of the North Pacific HIGH and a combination of Alaskan stations under the term "Alaska." Pressures from both of these points may have an important bearing on the weather of the United States, although the precise nature of the bearing has not yet been worked out. I have therefore summarized in the following table the most significant of the correlation coefficients between Honolulu pressures for the months December to February and June to August with the pressures of more or less remote regions both for contemporary pressures and for the pressure at the distant "center of action" 6 months previous. Chief interest therefore centers in the two columns headed "2 quarters before."

It is quite evident that the only significant coefficients for the 6 months previous with Honolulu are those for Port Darwin, Australia, and possibly Mauritius of plus 0.46 and 0.30, respectively. For the summer months, June to August, there is a positive correlation of 0.45 with Samoa and 0.73 for contemporary pressures. In winter, however, this correlation with Samoa is so small as to be insignificant. In this connection the point cannot be too strongly emphasized that the true importance of relations such as these is shown, not by the correlation coefficients and their probable errors alone, but by the *squares* of the coefficients. Thus for the Port Darwin-Honolulu pressure, .21 represents the true measure of contingency between them; for Mauritius-Honolulu this measure is but .09.

TABLE 1.—*Correlation coefficients, Honolulu pressure, and pressure at distant "centers of action"*

Pressure at—	December to February			June to August		
	2 quarters before	Contemporary	2 quarters after	2 quarters before	Contemporary	2 quarters after
Port Darwin	+0.46	+0.39	+0.11	−0.33	−0.67	−0.64
Mauritius	+.30	−.25	−.18	−.31	−.22	−.10
Central Siberia	−.20	−.29	−.39	+.07	−.16	−.09
Alaska	−.15	−.71	−.03	−.12	−.28	+.23
Southeast Australia	+.28	+.33	+.21	−.25	−.28	−.54
Azores	+.15	+.15	+.21	+.07	+.20	−.09
Charleston	+.09	−.20	+.21	+.10	−.08	+.30
South Orkneys	+.01	+.37	−.46	+.16	−.07	−.01
Samoa	+.08	+.19	+.03	+.45	+.73	+.50
South America	+.12	+.07	+.19	−.01	+.52	−.05

Finally, I conclude that the explanation of the warm weather experienced in the last part of January and during February, 1925, must be referred to the presence of an oceanic cyclone over the Gulf of Alaska which influenced the weather on the continent in two distinct ways: (1) It provided suitable atmospheric conditions whereby a number of rather ill-defined cyclonic systems were detached from the primary oceanic cyclone and passed

[4] Walker, Gilbert T., Memoirs of the Indian Meteorological Department, Vol. XXIV, Part IV, pp. 88–103.

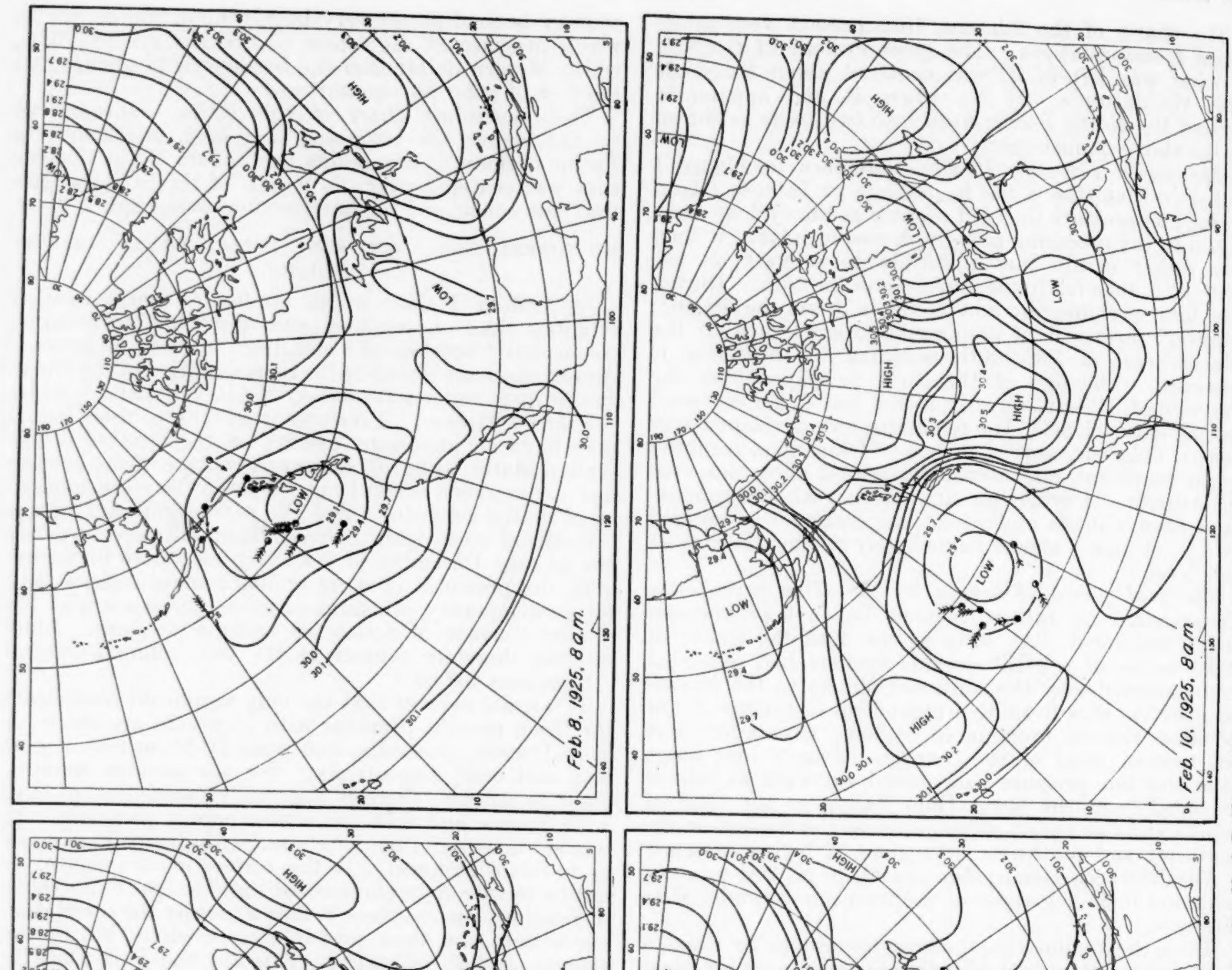

FIG. 3.—Pressure distribution, eastern North Pacific and North America, February 7–10, 1925

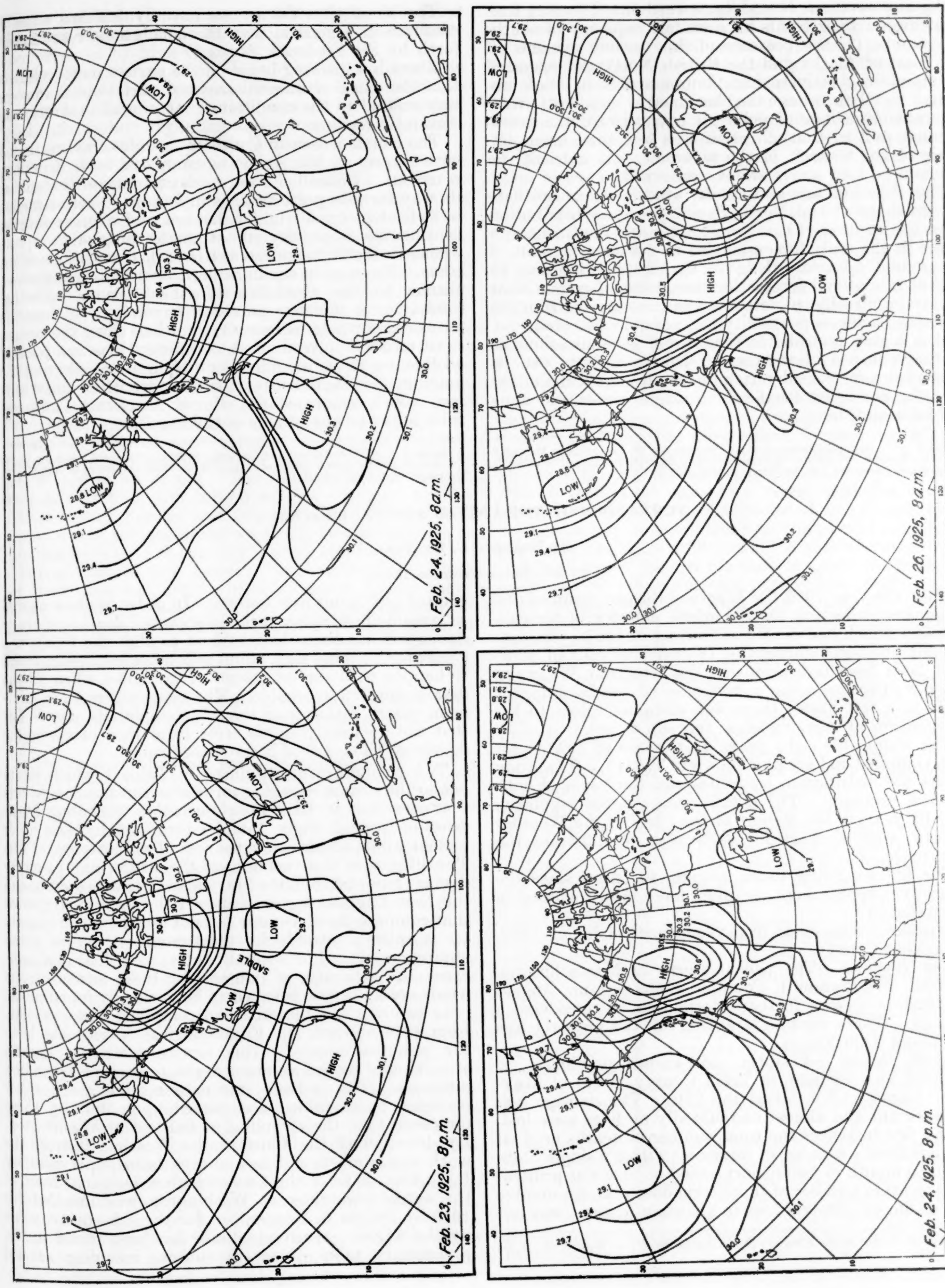

FIG. 4.—Pressure distribution, eastern North Pacific and North America, February 23–24, and 26, 1925.

along the northern boundary toward the Atlantic, thus inducing on their fronts an unusual frequency of southerly winds; (2) the presence of this oceanic cyclone off the coast of Alaska and the British Northwest operated to maintain relatively high temperatures in those regions, so that when the barometric gradients were favorable to a flow of polar air equatorward the gravitational pull in that direction was less than usual because of the warmth of the polar air. As a result, no pronounced cold waves swept southward.

The object of this and similar studies [5] is to evaluate the influence of the North Pacific pressure distribution upon the weather of the North American Continent as a factor in the daily forecasts, also to discover to what, if any, extent a foreknowledge of that distribution may be helpful in seasonal forecasting, assuming, of course, that it may be possible to forecast the pressure distribution over the Pacific, a possibility not yet demonstrated.

It is highly improbable that useful generalizations as to the sequence of weather in North America can be drawn from the consideration of the pressure distribution over the northeast Pacific for a single winter and none will be attempted.

The work thus far is not entirely fruitless since it confirms in a general way the conclusions recently set forth by Sir Frederick Stupart.[6]

There is a growing belief on the part of meteorologists that the cause of unusual seasonal variations is in some way related to the conditions that prevail in Arctic and Antarctic regions.

The North American Continent is unfavorably situated with respect to the Arctic as compared with European countries. Instead of a warm oceanic current that makes its way far into polar seas, as in Europe, North America is hedged in by a frigid polar sea and a great interior continental area devoid of meteorological outposts whence useful information as to weather conditions might come. Progress in ameliorating this need is being made, thanks to the Canadian Weather Service. Another hindrance to weather prevision beyond 24–36 hours is a lack of knowledge of free-air conditions along the western coast on the approach of an oceanic cyclone and back of all this lies the most difficult problem of anticipating the pressure distribution over the vast extent of water surface which separates the North American Continent from Asia and the islands of the Far East.

[5] Henry, A. J., Seasonal forecasting of precipitation, Pacific Coast States, MONTHLY WEATHER REVIEW 49: 213–219. Pressure over northeastern Pacific and weather in United States December, 1924, and January, 1925, 53: 5–10.

[6] Stupart, F., The variableness of Canadian winters. Presented before the British Association for the Advancement of Science at its Toronto meeting of August, 1924, abstracted in this Rev. 52: 351.

TORNADOES OF THE UNITED STATES, 1916–1923[1]

By HERBERT C. HUNTER

[Weather Bureau, Washington, D. C.]

With the year 1916 the Weather Bureau resumed the systematic collection for the whole country of tornado statistics which had ceased at the end of 1897. The important tornadoes during this 18-year interval had, however, been described, chiefly in the MONTHLY WEATHER REVIEW, likewise some minor ones of special interest; while in a few States there was sustained effort to list every storm of great violence, tornado or not.

The results for eight years, to the end of 1923, have been compiled and are now shown in Table 1. The study covers the distribution by States and the losses of both life and property. The details were printed regularly, year by year, in the Report of the Chief of the Weather Bureau, with a chart for each year to illustrate the occurrence.

The following new items, coming to notice since the respective reports went to press, have been included in the statistics:

Missouri.—One death from the tornado of June 1, 1917, in Jackson County.

New England.—The violent storm in Massachusetts, Norfolk, and Plymouth Counties, about 4 p. m., August 31, 1920, in view of further information, is considered a tornado. There were no fatalities, but the property loss was about $200,000.

North Dakota.—A storm, not known previously, is reported as a tornado, in Traill County, north of Mayville, August, 1919, about the 25th. The damage was unimportant and almost undoubtedly no lives were lost.

In a few instances the total number of deaths or total damage from a number of tornadoes within a single State during a month or other short period of time was printed, but the exact number of those tornadoes that did involve loss of life or property loss to a certain amount was not printed and is not now known. In order to show as well as possible how many tornadoes caused deaths or heavy damage it has been thought best to allot the totals in a somewhat unequal way, about as is most frequently found to happen with similar groups of tornadoes when all the details are still accessible. The cases where such allotment enters, rather than the complete details, are so few that the greatest possible error from this cause in the figures of Table 1 is of little consequence.

Two columns are introduced in Table 1 which relate not to the storms classed as tornadoes, but to severe winds that seem not to have been tornadoes, including hurricanes of tropical origin, thunderstorm squalls and other violent winds which can cause loss of property or of life. The division in these columns of the deaths and property damage reported from the Maryland-Delaware section and the New England section between the individual States that compose those sections can not now be made exactly (as is entirely possible for the tornadoes), but is given approximately. For several States, as a footnote indicates, the estimates of damage for these miscellaneous winds are known or believed to be decidedly incomplete.

In securing this material and compiling these reports, from 1916 onward, the Climatological Service has been the principal means. This service assigns a certain area, almost always an exact State, to each of 45 section directors. The tornado information, like much other material, is assembled and passed upon first by these directors, then the compiling is finished at Washington. By direction of the Chief of the Weather Bureau the work was started and has always been supervised by P. C. Day, head of the Climatological Division; most of the actual compiling at Washington was handled for 1916 by Joseph B. Kincer, but for the subsequent years by the writer. Much assistance has been found in the preliminary table of severe storms, including several

[1] Presented in part to the American Meteorological Society at Washington, D. C., Jan. 2, 1925.

kinds other than tornadoes, printed in the Monthly Weather Review since March, 1921; this has usually been prepared by Miss Grace W. Carter.

Newspaper sources available at Washington have been of considerable help, and the Weather Bureau officials at stations other than section centers have furnished much information regarding those tornadoes that came within moderate distances of their own stations.

The greatest credit, however, should be given to the section directors for their zealous, faithful efforts to secure accurate information and advise what the nature of each storm seems to have been. The present canvass has a marked advantage over earlier ones, covering 1897 and certain preceding years; for these directors, well distributed over the country and in touch with numerous sources of news within their sections, are apt to learn of storms in remote districts which would readily escape the notice of a single worker or a group in one city trying to collect items for the whole country.

Recently an attempt was made to test the completeness with which the newspapers of Washington report tornado information for the whole country. For over five months, not consecutive, every issue of two dailies, relying on different press services for their items, was thoroughly examined for news of violent storms, whether termed tornadoes or not. The result indicated that at least one-sixth of the tornadoes now reported by the Climatological Service and other Weather Bureau personnel would remain unknown if the two periodicals in question were used as the only sources of information.

It is a disadvantage, however, to have the final counts for the States rest chiefly upon so many diverse judgments. Naturally some directors are far more conservative than others in deciding whether a puzzling storm is to be classed as a tornado; and the storms that are difficult to classify form a large part of the whole number.

The Weather Bureau defines a tornado in Instructions for Preparing Meteorological Forms, paragraph 138*a*, thus:

> A tornado is a violent local storm, in connection with which is usually noted a well-defined, pendant, funnel-shaped cloud, with attendant rotary winds, often of sufficient violence to prostrate buildings and uproot trees, and leaving unmistakable evidence of rotary winds.

In practice, the information a section director can secure is very often inconclusive. A storm with much likeness to the tornado type may evidence so slight energy that it seems not to deserve the name "tornado"; again, the rotation around a vertical axis may not be established, though a trained observer can usually determine this point months after the occurrence by studying the débris. Furthermore, the total score of a State is much affected, at times, by the surmises as to whether two or three storm-visits a few miles and a few minutes apart, are properly to be considered but one tornado or rather two or three.

In passing upon the material assembled, the Climatological Division has occasionally changed the designation of a particular storm of puzzling character from the section director's decision of "possibly a tornado," which would count as 0 in the tables accompanying this article, to "probably a tornado," which counts as 1. That such transfer from one class to another is occasionally desirable may be judged from the fact that twice, within the 8-year period, a doubtful storm has crossed a State boundary, with the width and general character of its track not notably different in the two States, as far as information was secured; yet one section director had judged the storm "possibly a tornado, but probably not" and the other had reported it "probably a tornado."

The two States which seem to present the greatest contrasts in the matter of classifying difficult storms are Iowa and Georgia. It is thought that the period 1916–1923 was one of rather more than the normal number of violent local storms in Iowa, and of less than the normal number in Georgia; yet a careful contrasting of statistics for these States and those that border on them brings out striking results.

From the beginning of 1916 to the end of 1923 the count of tornadoes in Iowa was 66; the average count per State in the 6 States bordering on Iowa, 27.2; the count in Georgia, 4; the average per State in the 5 States bordering on Georgia, 19.2. The average number of deaths per tornado counted was in Iowa, 0.6; but in States bordering on Iowa, 2.5; in Georgia, 15.8; in States bordering on Georgia, 2.6. The average damage per tornado, as far as reported, was, in Iowa, approximately $67,000; in States bordering on Iowa, $114,000; in Georgia, $375,000; in States bordering on Georgia, $60,000.

It is difficult to avoid the opinion that the plan of assembling and passing upon the material lacks evenness; it seems probable that the methods for securing information and for classifying storms in Iowa, would, if employed in Georgia during the period, have reported more than 4 tornadoes; and, vice versa, that the Georgia methods would in Iowa have reported many less than 66.

There is a greater tendency on the part of most newspapers to brand as a "tornado" a violent storm which results in loss of human life than to apply the term to a similar storm which does not involve loss of life.

In the entire country, from 1916 to 1923, the information secured indicates 754 storms that should be classified as tornadoes, an average of 94 and a fraction per year. Two columns of Table 1 present the numbers by States, the first of them counting only those which originated within the State, but the other all those which affected any portion of the State, whether starting within it or outside it. The count by States of origin gives 753, the other tornado starting in Mexico and crossing the Rio Grande into Texas. No tornado seems to have crossed the Canadian boundary in either direction. The count by States of occurrence gives a total of 810–56 being due to tornadoes crossing State boundaries, a few storms crossing two such lines, but none more than two.

The annual count was greatest in 1917, when there were 121 tornadoes, while 65 was the smallest total for any one year of the eight. This is a smaller range in yearly numbers than would be expected by the chances of occurrence. In Table 2 certain statistics of the tornadoes are assembled by years and are presented with like statistics for the nine years studied by Professor Henry, 1889 to 1897, inclusive.[2]

Among the States for this 8-year period Arkansas leads in number of tornadoes with 76; afterwards come, in order, Kansas, Texas, Iowa, Missouri, and Oklahoma, the last-named reporting just 50. The greatest number for any one State during a single year is found in Arkansas for 1916, 32; while next to it is Missouri, which reported 30 in 1917.

In just eight States there seem to have been no tornadoes during this period. Of the eight, six are in the East, four of the six being of decidedly small area; the other two are in the far West. In the four Territories included in Table 1 there have been no tornadoes reported during the years it covers, nor, so far as known, during any other years.

[2] Reports of the Chief of the Weather Bureau, 1895–1896, 1896–1897, 1897–1898.

TABLE 1.—*Statistics of tornadoes, 1916–1923*

State or Territory	Number of tornadoes, 8 years		Most tornadoes in a year, and the year	Number of years when tornadoes were			Loss of life, 8 years, by—		Most tornado deaths in a year, and the year	Number of tornadoes—			Average loss of life per—		Aggregate reported property losses in thousands, 8 years, from—		Number of tornadoes causing losses of—		Greatest tornado losses in a year, and the year (thousands)
	Originating in—	Occurring in—		Fatal	Not fatal	Absent	Tornadoes	Winds not tornadoes		Fatal to 1 or more	Not fatal	Fatal to 10 or more	Tornado occurring	Fatal tornado	Tornadoes	Winds not tornadoes	$100,000 or more	$1,000,000 or more	
Alabama	30	35	8:1922	8	0	0	180	6	108:1920	[1] 18	[1] 17	[1] 5	5.1	[1] 10.0	$3,797	$4,274	[1] 9	1	$2,155:1920
Alaska	0	0	----------	0	0	8	0	[2] 1	----------	0	0	0	------	------	0	[2] 17	0	0	----------
Arizona	1	1	1:1916	0	1	7	0	2	----------	0	1	0	------	------	([3])	205	0	0	([3]) :1916
Arkansas	74	76	32:1916	7	1	0	231	8	91:1916	[1] 32	[1] 44	[1] 6	3.0	[1] 7.2	2,400	266	[1] 3	1	1,502:1921
California	1	1	1:1921	0	1	7	0	15	----------	0	1	0	------	------	17	4,808	0	0	17:1921
Colorado	7	7	2: ([4])	1	4	3	5	3	5:1922	2	5	0	0.7	2.5	160	74	1	0	130:1922
Connecticut	0	0	----------	0	0	8	0	[5] 0	----------	0	0	0	------	------	0	([6])	0	0	----------
Delaware	0	0	----------	0	0	8	0	[5] 3	----------	0	0	0	------	------	0	[5] 30	0	0	----------
District of Columbia	1	1	1:1923	0	1	7	0	[5] 1	----------	0	1	0	------	------	([3])	[5] 15	0	0	([3]) :1923
Florida	6	6	3:1919	1	2	5	1	37	1:1917	1	5	0	0.2	1.0	53	8,674	0	0	31:1919
Georgia	3	4	3:1921	2	0	6	63	17	33:1920	3	1	2	15.8	21.0	1,500	812	2	1	1,250:1920
Hawaii	0	0	----------	0	0	8	0	[2] 1	----------	0	0	0	------	------	0	([2]) ([3])	0	0	----------
Idaho	1	1	1:1916	0	1	7	0	0	----------	0	1	0	------	------	([3])	([3])	0	0	([3]) :1916
Illinois	23	24	7:1920	5	2	1	149	17	106:1917	12	12	2	6.2	12.4	7,536	706	9	3	3,342:1917
Indiana	15	20	9:1917	3	2	3	131	8	75:1917	11	9	6	6.6	11.9	5,016	1,775	8	2	3,200:1917
Iowa	63	66	13:1919	4	4	0	40	1	29:1918	10	56	1	0.6	4.0	4,446	650	12	0	2,450:1918
Kansas	68	69	18:1923	5	3	0	61	3	42:1917	[1] 12	[1] 57	2	0.9	[1] 5.1	3,622	1,658	11	0	1,870:1917
Kentucky	6	8	4:1917	1	3	4	75	34	75:1917	2	6	1	9.4	37.5	2,080	3,891	1	1	2,000:1917
Louisiana	13	13	5:1923	5	1	2	42	36	25:1923	9	4	1	3.2	4.7	1,260	6,807	2	0	965:1923
Maine	0	0	----------	0	0	8	0	[5] 1	----------	0	0	0	------	------	0	[7] 2	0	0	----------
Maryland	0	1	1:1923	0	1	7	0	[5] 1	----------	0	1	0	------	------	100	[5] 220	1	0	100:1923
Massachusetts	2	2	1: ([4])	0	2	6	0	[5] 4	----------	0	2	0	------	------	400	([6])	2	0	200: ([4])
Michigan	24	24	6:1920	2	6	0	16	45	12:1920	4	20	0	0.7	4.0	3,082	[7] 182	[1] 5	[1] 2	2,000:1920
Minnesota	9	12	3:1920	4	2	2	99	3	59:1919	4	8	2	8.2	24.8	4,767	[7] 60	3	2	3,500:1919
Mississippi	41	42	11:1921	8	0	0	257	5	135:1920	24	18	8	6.1	10.7	3,698	[7] 196	[1] 9	1	1,500:1920
Missouri	52	57	30:1917	5	3	0	123	9	84:1917	25	32	3	2.2	4.9	3,507	1,216	9	1	1,550:1917
Montana	9	9	7:1923	1	2	5	2	5	2:1923	1	8	0	0.2	2.0	4	45	0	0	4:1923
Nebraska	34	36	6: ([4])	3	5	0	7	3	3: ([4])	3	33	0	0.2	2.3	902	([6])	3	0	500:1918
Nevada	0	0	----------	0	0	8	0	0	----------	0	0	0	------	------	0	([3])	0	0	----------
New Hampshire	1	1	1:1922	0	1	7	0	[5] 0	----------	0	1	0	------	------	10	([6])	0	0	10:1922
New Jersey	2	2	1: ([4])	0	2	6	0	13	----------	0	2	0	------	------	([3])	235	0	0	([3]) : ([4])
New Mexico	8	8	3:1922	0	5	3	0	0	----------	0	8	0	------	------	19	1	0	0	12:1923
New York	6	6	2: ([4])	1	3	4	2	97	2:1920	1	5	0	0.3	2.0	335	4,073	2	0	200:1920
North Carolina	10	11	2: ([4])	4	4	0	8	1	3: ([4])	4	7	0	0.7	2.0	547	[7] 14	2	0	280:1920
North Dakota	17	19	5: ([4])	3	4	1	10	3	8:1923	4	15	0	0.5	2.5	128	1,171	0	0	70:1921
Ohio	18	23	7:1920	4	3	1	40	12	31:1920	8	15	2	1.7	5.0	3,187	[7] 200	10	0	1,512:1920
Oklahoma	46	50	15:1917	7	1	0	144	9	64:1920	[1] 18	[1] 32	4	2.9	[1] 8.0	2,632	2,034	[1] 9	0	1,045:1922
Oregon	0	0	----------	0	0	8	0	9	----------	0	0	0	------	------	0	250	0	0	----------
Pennsylvania	10	11	3: ([4])	3	2	3	4	13	2:1919	3	8	0	0.4	1.3	275	[7] 1	1	0	175:1918
Porto Rico	0	0	----------	0	0	8	0	[2] 0	----------	0	0	0	------	------	0	[2] 0	0	0	----------
Rhode Island	0	0	----------	0	0	8	0	[5] 0	----------	0	0	0	------	------	0	([6])	0	0	----------
South Carolina	18	18	8:1920	3	4	1	7	1	5:1922	3	15	0	0.4	2.3	278	[7] 47	0	0	171:1920
South Dakota	20	23	11:1918	3	4	1	6	5	4:1916	4	19	0	0 3	1.5	481	253	2	0	206:1916
Tennessee	21	26	8:1921	4	3	1	54	33	26:1917	11	15	2	2.1	4.9	1,041	969	4	0	395:1917
Texas	67	68	17:1921	6	2	0	152	301	64:1919	20	48	7	2.2	7.6	3,439	27,753	10	0	959:1922
Utah	1	1	1:1916	0	1	7	0	1	----------	0	1	0	------	------	([3])	50	0	0	([3]) :1916
Vermont	0	0	----------	0	0	8	0	[5] 0	----------	0	0	0	------	------	0	([3])	0	0	----------
Virginia	6	6	2:1922	1	4	3	1	3	1:1917	1	5	0	0.2	1.0	87	[7] 71	0	0	50:1917
Virgin Islands	0	0	----------	0	0	8	0	[2] 0	----------	0	0	0	------	------	0	([2]) ([3])	0	0	----------
Washington	1	1	1:1916	0	1	7	0	36	----------	0	1	0	------	------	([3])	[7] 361	0	0	([3]) :1916
West Virginia	0	0	----------	0	0	8	0	3	----------	0	0	0	------	------	0	21	0	0	----------
Wisconsin	8	11	3: ([4])	3	3	2	18	11	9:1918	4	7	0	1.6	4.5	1,380	3,005	2	0	715:1918
Wyoming	10	10	7:1923	1	3	4	1	1	1:1923	1	9	0	0.1	1.0	25	18	0	0	14:1923
Sum of State numbers	753	810	----------	------	------	------	1929	821	----------	255	555	54	------	------	62,211	77,110	132	15	----------
True number for country	753	754	121:1917	8	0	0	1929	821	508:1917	233	521	48	2.6	8.3	62,211	77,110	124	17	15,205:1920

[1] Partly estimated, because of present lack of details about aggregate losses.
[2] For two years only.
[3] No estimate, but some loss, probably unimportant.
[4] More than one year.
[5] Distribution of the Maryland-Delaware or the New England aggregates between the individual States estimated, at least in part.
[6] No estimate of any loss secured; losses probably considerable.
[7] Reported losses believed to be but a small part of total.

It has already been indicated that the total number of tornadoes is somewhat uncertain. If different compilers should work independently from the original information forward, their counts of the tornadoes would very likely differ considerably; but it is believed that they would vary but little when finding the aggregate loss of life from tornadoes, since the storms of puzzling character are not a large factor in causing deaths.

The total loss of life from 1916 to 1923 was 1,929; these deaths were the work of slightly less than one-third of the tornadoes, 233 out of the 754. More than a third of those tornadoes which crossed State lines caused fatalities in each of two States; and of the 810 tornado occurrences by States it is found 255 involved loss of life.

Among the 41 States in which tornadoes were reported (the District of Columbia counted), 11 escaped fatalities, and in 11 more the death toll per State, over the eight-year period, was less than 10. In other words, but 19 States had an aggregate loss of life from tornadoes of 10 or more, or an average per year of 1.25 or more. These items and many other similar ones are readily determined by inspection of Table 1.

The greatest loss of life in any State occurred in Mississippi, 257; Arkansas came next, with 231; while Alabama was third, with 180. Over one-third of the tornado deaths in the country during this eight-year period happened in one or another of these three States. Only 48 tornadoes, or about one tornado in each 16 occurring, took 10 or more lives, and but one among the 754 caused as many as 100 fatalities, and that one but 103—a tornado of very long path (293 miles), in Illinois and Indiana, May 26, 1917.

Among the years the greatest loss of life is found in 1917, with 508, very closely followed by 1920, with 498. No other year of the eight ran up a total greater than 205.

The smallest toll of a single year in the eight-year period was 109, in 1923.

TABLE 2—*Statistics of tornadoes in the United States by years*

Year	Number	Number of States with—[1]	Aggregate loss of life	Number of fatal tornadoes	Most deaths in a single tornado	Aggregate reported property losses (thousands)	Number of tornadoes causing losses of—	
							$100,000	$1,000,000
1889	21	12	36	10	18	$173	0	0
1890	59	21	194	23	76	4,450	6	1
1891	32	17	16	9	3	187	0	0
1892	44	17	75	17	17	1,118	3	0
1893	83	23	262	40	89	2,044	6	0
1894	57	19	114	26	48	1,193	2	0
1895	32	15	31	9	10	384	0	0
1896	66	25	520	24	306	14,448	6	1
1897	30	16	55	14	14	198	1	0
1916	86	25	140	23	[2] 30	2,511	6	1
1917	121	21	508	54	103	15,008	22	5
1918	81	22	134	30	36	7,631	20	1
1919	65	22	205	15	59	6,861	9	2
1920	87	28	498	29	87	15,205	24	7
1921	106	30	202	27	61	5,406	13	1
1922	108	28	133	37	16	6,630	21	0
1923	100	29	109	18	23	2,959	9	0

[1] Alaska and District of Columbia each count as 1; therefore 50 is the maximum possible score in this column.
[2] Rests on the allotment of 73 deaths caused by a group of 26 or more tornadoes; the exact details of occurrence not now available.

When we turn to the property loss from tornadoes, we again find a considerable uncertainty in the totals. There is not alone the question whether a certain storm is to be classed as a tornado; often no real information can be secured as to appraisal of the damage, though this is more frequently the case with rather unimportant tornadoes; a section director is likely to receive very diverse estimates from different sources; and, finally, the estimates obtained are often admitted to be but for a limited portion of the tornado track. Nevertheless, the aggregate of the estimates, as shown in Tables 1 and 2, is thought to give a fair idea of the total loss and of the distribution by States and by years. Anyone anxious to analyze the results with greatest care may review the detailed material printed in the Reports of the Chief of the Weather Bureau and elsewhere.

During the present study a definite figure has, in a very few cases, been substituted for a somewhat indefinite statement of amount of property loss, such as "several hundred thousand dollars."

The total loss of property reported as due to the tornadoes of these 8 years was in excess of $62,000,000. By years 1920 leads, with $15,205,000, but 1917 shows only a little less, the 2 years together having nearly one-half of the 8-year loss, as, it may be noted, they had more than half of the deaths. The year with least is indicated as 1916, with $2,511,500, but 1923 had only $2,958,750. It is probable that actually the loss of 1923 was the less serious, for the value of property showed a marked increase during the interval, and especially the estimates for 1916 can not be considered so complete as for later years, the system of securing reports being not yet well started, and many helpers finding it not feasible to set a figure in dollars for the damage described.

As with loss of life, the range from year to year in the figures for property losses is much greater in proportion than the range in actual number of tornadoes counted. (See Table 2.)

Among the States, for the 8-year period, Illinois reports considerably the largest aggregate, over $7,500,000; Indiana comes next, with almost exactly $5,000,000, while Minnesota and Iowa are indicated as not far behind Indiana. The largest property loss from a single tornado was in Minnesota, $3,500,000, June 22, 1919, in and near Fergus Falls; next to this was the tornado of very long path, in Illinois and Indiana, May 26, 1917, when the damage amounted to about $3,000,000.

As inspection of the detailed statements about the several tornadoes will indicate, effort has been made to present information, when feasible, covering nine important points for each storm. This paper summarizes but three of those nine points—State of occurrence, loss of life, and loss of property.

The other six items, while less important from a business standpoint, have no little interest. They are: Month of occurrence, hour of the day, length of path, width of path, direction of advance of the tornado, and speed of advance. It is only rarely that a good estimate of the last-named item can be secured or made, and as to some of the others there is frequently little information, at least of such definite character as to make possible tabulation and summation.

It is not feasible at present to summarize the data on these six points. However, it is thought the results, if found, would not differ very greatly from those ascertained by Finley,[3] except that the occurrence by months probably would show relatively fewer during the summer and early fall and more during the spring months.

The period of eight years chosen for this compiling is particularly convenient for comparison with the numbers of tornadoes occurring by States which were found by the late Professor Abbe and presented by him in tabular form.[4]

In the count Abbe rather likely took the numbers for the States which Finley presented in his chart for years down to the end of 1881, and subtracted from those numbers the tornadoes which he counted from the detailed list as occurring before 1874[5]; these were relatively few, Finley having studied chiefly the years 1874–1881. The numbers for Finley's period, as presented by Abbe, are reprinted without change in the third column of Table 3.

The second column reprints the respective areas of the States, expressed in units of 10,000 square miles, the area of Virginia being corrected from that formerly printed.

The fourth column covers a span of nine years, so as to include the full period that was studied in detail by Henry. The figures which were shown by Abbe for 1889–1896 seem to have been for but seven years and a half, the period covered in the first printing of details by Henry.[6]

Therefore the figures which were printed in the Abbe table have been increased to include the tornadoes of the latter half of 1896 and all the tornadoes, which were comparatively few and unimportant, that are shown for the year 1897. Also a few tornadoes which occurred between the beginning of 1889 and June 30, 1896, are considered to have been unintentionally missed in the counting, and are now counted in; these are mentioned below.

Even with the increases so made, the number of counts for the country during the nine-year period, 1889–1897, is somewhat smaller than the number for 1874–1881, and much smaller than the number for 1916–1923, for which period the figures are brought from Table 1 to the fifth column of Table 3.

[3] Finley, John P. Character of 600 tornadoes. (U. S. Signal Service: Professional Paper 7; Washington, 1882.)
[4] Tornado frequency per unit area. MONTHLY WEATHER REVIEW, June, 1897, 25:250. The table was reprinted, with a correction as to area of South Dakota, in the paper noted in the next line.
Simpson, Howard E. Tornado insurance. MONTHLY WEATHER REVIEW, December, 1905, 33:534–539.
[5] Finley. As above.
[6] Report of the Chief of the Weather Bureau, 1895–1896.

TABLE 3.—*Frequency of tornadoes and tornado deaths, and amounts of property losses*

State or Territory	Area, in units of 10,000 square miles	Aggregate number of tornadoes				Average number of tornadoes per year		Total loss of life from tornadoes			Average loss of life			Aggregate reported property losses from tornadoes (thousands)	
		1874–1881, 8 years (Finley)	1889–1897, 9 years (Henry)	1916–1923, 8 years (Clim. Service)	Sum, 25 years	Per State	Per unit area	1889–1897	1916–1923	Sum, 17 years	Per tornado occurring	Per State per year	Per unit area per year	1889–1897, 9 years	1916–1923, 8 years
Alabama	5.1	12	14	35	61	2.4	0.47	2	180	182	3.7	10.7	2.1	$170	$3,797
Alaska	51.7	0	0	0	0			0	0	0				0	0
Arizona	11.4	2	0	1	3	0.1	0.01	0	0	0	0	0	0	0	(1)
Arkansas	5.2	8	23	76	107	4.3	0.83	20	231	251	2.5	14.8	2.8	582	2,400
California	15.8	1	0	1	2	0.1	0.01	0	0	0	0	0	0	0	17
Colorado	10.4	1	2	7	10	0.4	0.04	0	5	5	0.6	0.3	(2)	1	160
Connecticut	0.5	2	0	0	2	0.1	0.20	0	0	0				0	0
Delaware	0.2	0	0	0	0			0	0	0				0	0
Florida	5.9	5	1	6	12	0.5	0.08	0	1	1	0.1	0.1	(2)	2	53
Georgia	5.8	29	13	4	46	1.8	0.31	26	63	89	5.2	5.2	0.9	254	1,500
Idaho	8.6	0	0	1	1	(2)	(3)	0	0	0	0	0	0	0	(1)
Illinois	5.5	50	30	24	104	4.2	0.76	201	149	350	6.5	20.6	3.7	3,283	7,536
Indiana	3.4	24	8	20	52	2.1	0.62	0	131	131	4.7	7.7	2.3	44	5,016
Iowa	5.5	26	32	66	124	5.0	0.91	178	40	218	2.2	12.8	2.3	608	4,446
Kansas	8.1	55	53	69	177	7.1	0.88	103	61	164	1.3	9.6	1.2	967	3,622
Kentucky	3.8	5	12	8	25	1.0	0.26	123	75	198	9.9	11.6	3.1	2,933	2,080
Louisiana	4.1	11	10	13	34	1.4	0.34	22	42	64	2.8	3.8	0.9	172	1,260
Maine	3.5	3	3	0	6	0.2	0.06	3	0	3	1.0	0.2	0.1	13	0
Maryland	1.1	8	3	1	12	0.5	0.45	3	0	3	0.8	0.2	0.2	31	100
Massachusetts	0.8	7	1	2	10	0.4	0.50	8	0	8	2.7	0.5	0.6	60	400
Michigan	5.6	13	8	24	45	1.8	0.32	50	16	66	2.1	3.9	0.7	649	3,082
Minnesota	8.4	21	26	12	59	2.4	0.29	35	99	134	3.5	7.9	0.9	595	4,767
Mississippi	4.7	9	20	42	71	2.8	0.60	45	257	302	4.9	17.8	3.8	316	3,698
Missouri	6.5	40	17	57	114	4.6	0.71	174	123	297	4.0	17.5	2.7	10,734	3,507
Montana	14.4	1	0	9	10	0.4	0.03	0	2	2	0.2	0.1	(2)	0	4
Nebraska	7.6	14	22	36	72	2.9	0.38	12	7	19	0.3	1.1	0.1	688	902
Nevada	11.2	1	0	0	1	(2)	(3)	0	0	0				0	0
New Hampshire	0.9	3	0	1	4	0.2	0.22	0	0	0	0	0	0	0	10
New Jersey	0.8	5	7	2	14	0.6	0.75	4	0	4	0.4	0.2	0.2	81	(1)
New Mexico	12.1	1	0	8	9	0.4	0.03	0	0	0	0	0	0	0	19
New York	4.7	20	7	6	33	1.3	0.28	5	2	7	0.5	0.4	0.1	76	335
North Carolina	5.1	14	3	11	28	1.1	0.22	3	8	11	0.8	0.6	0.1	22	547
North Dakota	7.1	4	2	19	25	1.0	0.14	0	10	10	0.5	0.6	0.1	(3)	128
Ohio	4.0	21	9	23	53	2.1	0.52	8	40	48	1.5	2.8	0.7	207	3,187
Oklahoma	6.9	1	18	50	69	2.8	0.40	59	144	203	3.0	11.9	1.7	175	2,632
Oregon	9.5	0	1	0	1	(2)	(3)	[4] 5	0	[4] 5	[5] 5.0	0.3	(3)	(1)	0
Pennsylvania	4.6	17	14	11	42	1.7	0.37	44	4	48	1.9	2.8	0.6	634	275
Rhode Island	0.1	0	0	0	0			0	0	0				0	0
South Carolina	3.4	13	4	18	35	1.4	0.41	1	7	8	0.4	0.5	0.1	15	278
South Dakota	7.6	5	22	23	50	2.0	0.26	13	6	19	0.4	1.1	0.1	94	481
Tennessee	4.6	15	10	26	51	2.0	0.43	4	54	58	1.6	3.4	0.7	90	1,041
Texas	27.4	18	40	68	126	5.0	0.18	144	152	296	2.7	17.4	0.6	682	3,439
Utah	8.4	0	0	1	1	(2)	(3)	0	0	0	0	0	0	0	(1)
Vermont	1.0	2	0	0	2	0.1	0.10	0	0	0				0	0
Virginia	4.0	9	3	6	18	0.7	0.17	2	1	3	0.3	0.2	(2)	3	87
Washington	7.0	0	0	1	1	(2)	0.01	0	0	0	0	0	0	0	(1)
West Virginia	2.3	1	1	0	2	0.1	0.04	2	0	2	2.0	0.1	(2)	3	0
Wisconsin	5.3	11	10	11	32	1.3	0.25	4	18	22	1.0	1.3	0.2	8	1,380
Wyoming	9.8	1	0	10	11	0.4	0.04	0	1	1	0.1	0.1	(2)	0	25

[1] No estimate, but some loss, probably unimportant.
[2] Less than 0.05.
[3] Less than 0.005.
[4] Aggregate only $300.
[5] Evaluation of "several."

The 1896–1897 report, containing the only list for the last half of 1896, reprints the items for the first six months, adding accounts of several tornadoes during that period which came to notice too late for including in the earlier printing. With respect to one tornado in Kansas, designated 11a in the earlier printing, the omission from the list as reprinted is thought unintentional, so the tornado is now counted.

Three omissions before 1896 were noted and have been corrected in carrying the numbers to Table 3. The 0's of West Virginia and Oregon were each changed to 1, for the lists indicate a tornado in each State, the dates being, respectively, May 30, 1889 (No. 9), and June 3, 1894 (No. 19). Mention in the MONTHLY WEATHER REVIEW [7] was noticed of a tornado at Baird, Tex., July 25, 1895, which caused one death, yet is unlisted in the tornadoes of the year.

Owing to the political developments since 1897, data for Indian Territory, where presented separate from the like items for Oklahoma, are now included in the Oklahoma figures. The counts for Oklahoma and Texas seem to show very marked increases in number of tornadoes occurring, but these gains are thought to be chiefly a matter of more complete reporting, following on settlement and development of large portions of those States which were but very little used till within a comparatively few years.

To the eastward of Oklahoma and Texas, however, the count of tornadoes for 1916–1923 is found to show a very marked gain in number, far greater than the average gain of the whole country. In Alabama and Mississippi, where over twice as many were noted per year as were reported a generation ago, it seemed wise to examine the details with special care. As no extensive new settlements have been made recently in these States, it seemed likely that attention might now be paid to tornadoes causing no deaths or few, as compared with failure in the earlier periods to report such storms. But inspection shows that the Henry period included in these States an even larger proportion of no-death and few-death storms than the recent period. So the large increase in number reported seems to mean a genuine increase in occurrences—the recent years chanced to have many.

Yet considering the whole country, the moderate increase in number since the 18-year interval is thought to be considerably, but by no means wholly, due to

[7] MONTHLY WEATHER REVIEW, July, 1895, 23:244.

change in method of counting when individual tracks are not far distant, not in line, and yet are distinct from one another, or substantially so, from start to finish. The tornado occurrences in northern Texas, May 15, 1896, were counted but 1, while the present method would be to count 5, for 5 distinct clouds and paths were noted. Had the simultaneous tornadoes of May 4, 1922, at Austin, Tex., 3 miles apart, been handled in the 1890's, the count probably would have been but 1, and not the recent count of 2. In the very nature of things, counting of tornadoes can never be on as satisfactory a basis as the counting of sheep or of farmhouses.

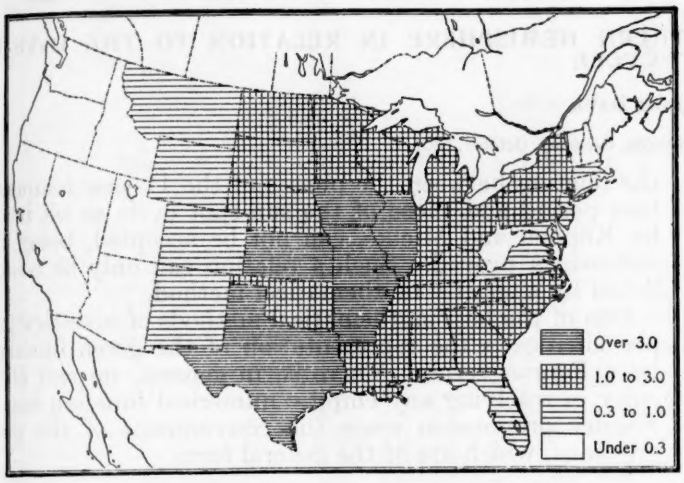

FIG. 1.—Average occurrence of tornadoes, per year per State, for 25 years

The sum of tornadoes for the three detached periods, 25 years altogether, is placed in the sixth column of Table 3. The seventh and eighth columns indicate the average number per year in each State as a whole and the average per year per unit area in each State. These three columns follow the plan of the three right-hand columns of the Abbe table. Figure 1 indicates graphically the average annual number per State.

The sums of the State numbers for the Finley, the Henry, and the recent periods, are 509, 449, and 810, respectively, or 1,768 for the 25 years. The true numbers for the whole country, from scanning of Finley's and Henry's lists and from Table 1, seem to be 506, 424, and 754, therefore 1,684 in all, which means an average of 67 tornadoes counted each year.

The two smallest States, Rhode Island and Delaware, are indicated as without tornadoes during the 25 years. In the former, however, Finley reports a tornado as having occurred during August, 1838.[8]

While tornadoes are evidently infrequent in the far West, yet no State there seems to be quite without them. In Oregon and Washington tornadoes and severe local winds seem not to have been reported yet from any point west of the Cascade Range.[9] Examining the whole area west of the Continental Divide, we find but two tornadoes involving loss of life, in Oregon and Montana, respectively.

In 1922 Colorado reported a few deaths by tornadoes, and in 1924 others occurred. This State extends farther eastward than either Wyoming, which is north of it, or New Mexico, south of it. If a line be drawn across Colorado from the southeastern corner of Wyoming to the northeastern corner of New Mexico, it will appear that all these deaths just referred to happened to eastward of the line.

The ninth to fourteenth columns of Table 3 are given to statistics of losses of life, those for the recent period being brought from Table 1 and those for 1889–1897 being compiled from the printed lists, with a very few allotments necessary when a tornado crossed a State border and the death toll for only the entire path is now available. For the Finley period even approximate statistics are not to be had. Totals for 17 years are computed, and division by the numbers of tornadoes occurring during those years (not printed) furnishes the average losses of life per tornado occurring. Average losses per year and per unit area per year are presented in the next two columns.

The tornado deaths for the country total 1,303 for the Henry period, and 3,232 for the 17 years. Per tornado occurring, 3,232 divided by 1,178, the average is 2.7; but per fatal tornado the average is 8 (3,232 divided by 405). The average number of deaths per year per State is indicated by Figure 2.

The two right-hand columns of Table 3 are used for data as to property losses. Again the Finley period does not yield information that can be put into statistical form, so only the years covered by the columns for losses of life are included.

The statistics by States for losses by tornadoes during 1889–1897 almost exactly follow those presented by Henry,[10] but some revisions have been made. The immense loss of the St. Louis tornado, May 27, 1896, instead of being placed wholly in the Missouri column, is now divided between that State and Illinois, according to the details printed at the time.[11]

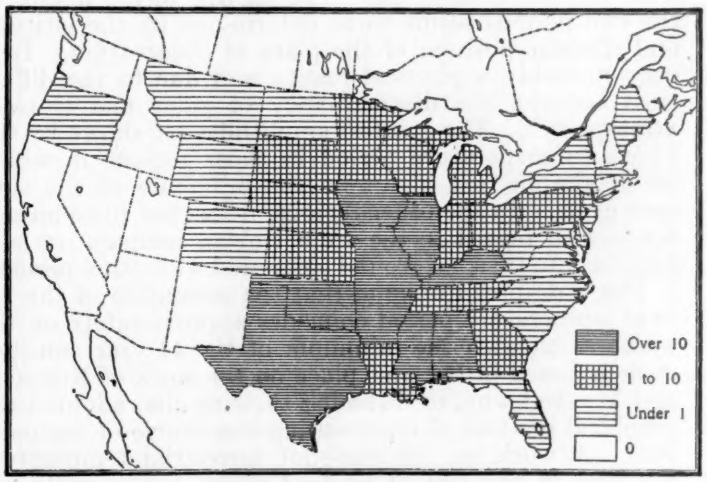

FIG. 2.—Average loss of life from tornadoes, per year per State, for 17 years

The other losses of 1896 have been computed over again from the list for the entire year, the loss of the dropped Kansas tornado, No. 11a in the first printing, being included.

The change in the value of the dollar, since the period studied by Henry, has been so great that it is considered unjust to add the 1889–1897 losses, State by State, to the 1916–1923 losses, and then compute averages. In States like Missouri and Pennsylvania, for which the greater number of dollars is stated for the earlier period, the computed averages would not be properly comparable with the averages for such States as Indiana, North

[8] Finley, as above, p. 4.
[9] This statement does not apply to winds covering belts many miles broad and sustained for a longer period than the thunder squall. Such winds, however, are included in the two columns of Table 1 stating deaths and losses from winds not tornadoes.

[10] Report of the Chief of the Weather Bureau, 1897–1898, p. 304.
[11] MONTHLY WEATHER REVIEW, March, 1896, 24: 80

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Dakota, and Wisconsin, where the damage of the early period was quite insignificant compared with that of the later period.

The canvass of the country by the Climatological Service is continuing. The synopsis for 1924 has not yet (May, 1925) been prepared, but enough is already known to make sure that the year will include a greater property loss from tornadoes than that of any one year covered by Table 2, that is, the figure in dollars will be a larger one; it will probably be the highest figure for a year in the country's history. Furthermore, 1925 has already witnessed (March 18) the most serious single tornado ever known, and so the 1925 death toll is expected to exceed that of any previous year, save perhaps 1884, and its figure for damage will very likely surpass that of 1924.

In handling the reports of tornadoes the writer has at times noticed how narrowly a violent storm escaped being entirely unreported. It is thought that a few tornadoes, though probably not many, still occur in sparsely settled parts of the country without any news of them reaching the Weather Bureau.

In closing, the writer wishes gratefully to acknowledge the advice and assistance given by many Weather Bureau colleagues, particularly by Prof. A. J. Henry and Mr. P. C. Day; also by Dr. Charles F. Brooks.

THE 11-YEAR PERIOD OF TEMPERATURE IN THE NORTHERN HEMISPHERE IN RELATION TO THE 11-YEAR SUN-SPOT CYCLE

By Dr. FRANZ BAUR

[Wetter- und Sonnenwarte, St. Blasien, Germany, October, 1923]

The analytical method for investigating the periods in the course of the weather is essentially superior to the graphical method which has hitherto been almost exclusively adopted. Its application to the annual mean temperature for the period 1876–1919 of a number of European and North American meteorological stations shows that the maximum of the 11-year temperature period on the whole earth in no way coincides with regard to time even approximately with the minimum of solar activity as has been assumed up to now. In large areas of the Temperate Zone of the Northern Hemisphere the maximum of the 11-year temperature period occurs between the minimum and maximum of the sun-spot cycle; in some continental European regions it even coincides with the maximum itself. The shifting of the phases of the two periods seems to be determined by the latitude and climatic position of the place of observation. It is very probably a physical reality and due to the difference between the diathermancy of polar and tropical atmospheres. The greatest amplitudes are shown by the 11-year temeperature period in those regions in which its maximum falls about on the minimum of the sun-spot cycle. In the other regions, it has but little importance with regard to the annual mean temperature and falls far into the background compared with other periods.

The widespread opinion that the maximum of the 11-year temperature period coincides approximately on the whole earth with the minimum of the 11-year sun-spot cycle is based in the first place on the work of Köppen [1] and Mielke,[2] who, in deducing their results, adopted the graphical method of representing the course of temperature. A work on the sun-spot terrestrial temperature relations in the United States [3] which has recently appeared is also based on this method. The graphical method is, however, little suited to the investigation of periodic phenomena, for with it are necessarily connected smoothing processes in order to eliminate from the graph lesser periods than the required one, or the one under investigation. These smoothing processes tend both to obscure some really existing period and to make apparent a nonexistent one. But more important is the fact that these smoothings of the graph change in most cases the phase of the required period considerably. Therefore, the relation between the phases of the 11-year temperature period and those of the sun-spot cycle as set forth by Köppen and Mielke, can not be accepted, being insufficiently proved. Such a relation can only be established by a strictly mathematical method.

One of the best mathematical methods of investigating periodicities is the representation of the given function by a Fourier series. There is, in general, no real difficulty in resolving any empiric numerical function into a Fourier progression since the convergence of the progressions, which are of the general form

$$f(t) = \tfrac{1}{2}a_0 + a_1 \sin t + a_2 \sin 2t + \ldots\ldots \\ + b_1 \cos t + b_2 \cos 2t + \ldots\ldots$$

is determined in large measure by mathematical theory. In meteorology, however, the problem becomes difficult, since it is a matter of compound functions of the form

$$f(t) = \tfrac{1}{2}r_0 + r_1 \sin (T_1 t + \phi_1) + r_2 \sin (T_2 t + \phi_2) + \ldots\ldots$$

whose terms are not of definite number but, in general, of any number of incommensurable periods. Even if, as in the given example, it is only a matter of calculating a single period, the amplitude and phase resulting from Fourier's analysis for this one period may yet be falsified by the coexistence of other incommensurable periods. For each ordinate of the unsmoothed course of a phenomenon subject to periodic oscillations is the sum of several ordinates belonging to different periods. In order to eliminate the influence of other periods in determining the amplitude and phase of a period by means of Fourier's analysis, it is necessary either to examine a very large series of observations such as hardly yet exists in most cases for meterological purposes, or else a period of time must be made the basis of the calculation which is, at least approximately, a multiple of each of the existing periods.

Since in previous works [4] I have come to the conclusion that very probably there are contained in the fluctuations of temperature both a 2.4 and a 7.2 year period, I chose, for the determination of the phase shiftings of the 11-year temperature period, a period of 44 years, for this is approximately a multiple of 2.4, 7.2, and 11 years. The choice of a still longer period of time would not have been feasible, for the reason that the period is not exactly 11 years, but 11.1–11.4, so that in dividing the whole period of observation into intervals of 11 years

[1] Köppen W., Ueber mehrjährige Perioden der Witterung, insbesondere über die 11-jährige Periode der Temperatur. Zeitschr. der Oesterr. Gesellschaft für Meteorol. VIII, 1873, XV, 1880, XVI, 1881; Meteorol. Zeitschr. VIII, 1891, XXXI, 1914.

[2] Mielke Johannes, Die Temperaturschwankungen 1870–1910 in ihrem Verhältnis zu der 11-jährigen Sonnenfleckenperiode. Archiv der Deutschen Seewarte, XXXVI, No. 3, 1913.

[3] Henry A. J., Sun spots and Terrestrial Temperature in the United States. Mo. Weather Review, May 1923, vol. 51, pp. 243–249.

[4] e. g., F. Baur, Die Veränderlichkeit der Temperatur aufeinanderfolgender Monate nnd die periodischen Schwankungen der Jahrestemperatur in Deutschland, Abstract in Mo. Weather Review, April, 1922.

each, the phase of the oscillation in the fifth interval compared with that in the first would already be shifted by about a year. The 44 yearly averages were arranged according to the following scheme in 4 rows of 11 terms each, and of the 4 values in each column the average (M_1 M_2, etc.) was obtained. From the 11 mean values thus obtained are then calculated the amplitude and phase of the first term of Fourier's series by the known method.

$$\begin{array}{llll}
y_1 & y_2 & y_3 \text{-------------------------} & y_{11} \\
y_{12} & y_{13} & y_{14} \text{-------------------------} & y_{22} \\
y_{23} & y_{24} & y_{25} \text{-------------------------} & y_{33} \\
y_{34} & y_{35} & y_{36} \text{-------------------------} & y_{44} \\
\hline
S_1 & S_2 & S_3 \text{-------------------------} & S_{11} \\
M_1 & M_2 & M_3 \text{-------------------------} & M_{11}
\end{array}$$

Besides the annual mean temperatures given in Table 1, there were also analyzed the annual temperature deviations for 10 districts of the United States, given in Table 4 of the above-mentioned work by Alfred J. Henry.[5] The position of the respective districts is shown in Figure 1. The deviations for the tenth district were not used, since in the table published by Henry, they are, apparently in consequence of a mistake, absolutely identical with those of the fourth district.

The results of the calculations have been arranged in Table 2. The phases in brackets (southern Italy, Ponta Delgada and Batavia) were obtained from a different period from all the others. The amplitudes were all changed into degrees Centigrade. The study of the table teaches first that the temperature maximum coin-

TABLE 1.—*Annual means of temperature*

Year	A	B	C	D	E	F	G	H	J	K	L	M	N	O	P	Q	R	S	T	U
	° C.	° C.	° C.	° C.	° C.	° F.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° C.	° F.	° F.	° F.	° F.	° C.
1874	16.3	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------
1875	16.6	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------
1876	17.4	9.80	8.3	10.6	8.47	50.00	6.9	5.8	2.8	2.25	20.4	−8.9	−1.4	3.1	------	43.9	50.5	55.4	77.0	25.89
1877	17.0	10.08	8.6	10.4	8.75	49.46	7.2	5.25	3.0	1.5	24.2	−8.1	−1.6	2.5	------	45.8	52.6	56.4	77.0	26.28
1878	17.0	9.16	8.7	10.0	9.00	49.41	8.1	6.65	4.9	2.8	22.1	−7.4	−0.3	2.2	------	48.5	52.9	57.0	77.1	26.64
1879	16.4	8.21	7.3	8.2	7.14	46.23	6.5	5.6	3.9	2.55	21.7	−8.0	−1.6	2.6	------	46.1	51.3	56.2	77.1	25.85
1880	16.9	9.91	8.85	10.6	8.83	49.17	7.6	6.65	3.7	1.95	21.4	−8.4	−1.9	3.7	16.9	46.7	52.2	56.9	78.7	25.65
1881	17.1	9.65	7.7	9.8	7.69	48.13	6.2	5.15	2.3	1.05	21.8	−7.9	−1.2	1.0	17.1	46.4	52.2	57.9	78.1	26.13
1882	17.0	9.44	9.1	10.2	8.92	49.44	8.5	7.1	5.1	3.0	20.4	−10.0	−3.6	1.9	17.7	47.1	51.5	57.3	78.2	25.78
1883	15.9	9.24	8.3	9.9	8.38	48.93	7.2	6.65	4.2	4.15	21.0	−7.3	−3.6	3.9	17.1	43.4	50.6	55.8	78.4	25.88
1884	15.9	10.09	8.95	10.5	8.98	50.09	8.0	7.05	4.1	3.25	20.6	−10.3	−4.7	3.8	16.9	43.9	51.6	56.3	77.6	25.80
1885	16.6	9.82	8.65	9.8	8.19	48.08	7.6	5.9	4.1	1.55	21.3	−8.3	−2.0	2.2	17.5	41.4	49.8	51.7	76.5	26.00
1886	16.7	9.92	8.65	10.3	8.43	48.24	7.4	6.05	4.5	3.0	20.9	−10.0	−2.7	2.2	17.5	44.0	51.0	53.0	75.9	26.09
1887	16.8	8.56	7.8	8.8	7.46	47.47	7.1	6.55	4.9	2.7	21.4	−11.3	−2.8	1.9	17.6	44.6	51.9	55.3	76.1	25.70
1888	16.4	8.76	7.75	9.0	7.25	47.34	6.2	5.45	2.3	1.4	21.3	−8.8	−1.2	1.8	17.4	42.8	51.5	53.8	76.5	26.20
1889	16.3	8.81	8.0	9.5	7.99	48.59	7.2	7.3	4.5	3.6	21.5	−10.0	−2.2	3.4	17.8	46.1	53.5	54.8	76.0	26.41
1890	16.0	8.55	8.15	9.3	8.05	48.33	7.7	6.85	5.2	3.85	21.2	−9.2	−2.5	4.0	18.0	46.4	53.8	56.4	76.6	25.78
1891	16.1	8.76	8.0	9.5	8.04	47.79	7.3	6.65	4.5	2.75	21.5	−10.3	−2.5	2.9	17.9	46.7	53.8	54.7	76.1	26.25
1892	16.7	9.57	8.45	10.2	8.05	47.31	7.4	5.65	3.0	1.15	21.3	−8.1	−0.9	1.0	17.3	44.6	51.9	53.3	75.7	26.00
1893	16.4	10.12	8.4	10.8	8.38	50.38	6.7	6.25	2.5	0.9	20.2	−7.8	−1.3	3.1	17.6	43.8	51.3	53.7	76.9	25.71
1894	16.5	9.72	8.85	10.4	9.00	49.24	7.6	7.35	5.4	3.7	20.7	−10.4	−3.3	4.2	16.8	47.6	53.7	56.1	76.7	25.88
1895	16.4	9.27	8.0	9.9	8.02	48.26	7.3	5.85	4.0	2.7	20.8	−7.2	−0.6	3.2	16.6	45.1	51.4	53.6	75.9	26.02
1896	16.1	8.75	8.15	9.8	8.28	48.69	7.7	7.0	5.1	3.1	20.8	−10.1	−2.9	3.6	17.7	47.2	51.2	55.6	76.4	26.38
1897	16.5	9.74	8.8	10.6	8.59	49.49	7.6	6.75	4.8	2.75	20.3	−9.3	−2.5	3.5	17.1	46.8	51.6	55.3	77.2	26.60
1898	17.1	9.97	9.6	10.7	9.20	50.43	8.0	6.8	4.7	2.9	20.4	−10.6	−4.2	3.3	17.6	47.3	52.9	55.9	76.6	26.11
1899	16.8	10.17	8.65	10.8	8.84	50.11	7.7	6.7	3.5	1.15	20.6	−8.5	−2.2	3.1	17.4	46.8	52.6	55.0	76.9	25.98
1900	17.1	10.18	9.3	11.1	9.11	49.64	7.9	6.15	3.4	1.05	21.2	−6.9	−1.2	3.5	17.8	47.9	54.3	56.0	75.9	26.37
1901	16.5	9.11	8.5	10.0	8.39	48.84	7.7	7.0	4.7	3.2	21.6	−8.0	−0.9	4.0	17.6	46.7	52.3	54.0	74.7	26.23
1902	16.7	9.30	8.05	9.9	7.81	48.54	6.0	5.6	2.4	1.45	21.0	−7.7	−1.5	2.6	17.1	47.2	52.6	54.7	76.4	26.37
1903	16.4	9.39	9.0	10.3	9.13	49.30	8.1	6.7	5.4	2.9	19.8	−7.9	−1.7	3.1	17.0	46.0	52.5	54.3	76.5	26.28
1904	16.7	10.13	9.25	10.4	8.99	48.97	7.0	6.4	3.6	2.15	19.8	−9.2	−2.3	3.9	16.9	44.7	49.9	53.2	76.1	25.85
1905	16.3	9.43	9.0	9.9	8.80	49.03	7.6	6.75	4.7	2.7	20.3	−7.6	−1.5	3.7	17.4	45.8	52.0	54.2	76.8	26.51
1906	16.0	9.68	8.95	10.5	9.13	49.60	8.0	7.2	5.3	2.3	20.4	−8.9	−2.8	2.9	17.4	48.0	53.5	55.4	76.4	26.47
1907	16.5	9.48	8.85	10.1	8.56	48.68	6.7	6.35	3.4	3.1	19.6	−9.4	−3.1	2.6	17.5	45.5	51.2	54.2	77.4	26.02
1908	16.2	9.21	8.3	9.8	8.18	49.36	6.8	7.05	4.0	2.6	19.6	−7.3	−1.6	4.2	16.8	47.8	53.5	56.6	76.8	25.86
1909	15.9	8.85	8.15	9.5	8.09	48.09	7.0	5.95	4.1	2.0	20.6	−7.9	−1.4	3.6	17.2	46.3	52.7	54.9	76.6	25.90
1910	16.1	9.52	9.1	10.3	9.28	49.21	8.5	7.25	5.8	2.85	19.9	−9.0	−2.4	3.4	17.5	47.1	53.1	54.4	75.2	26.22
1911	16.7	10.38	9.45	11.3	9.82	50.71	8.3	7.45	4.9	3.2	20.0	−8.5	−2.3	3.4	17.4	48.3	52.9	56.7	77.5	26.30
1912	16.3	9.28	8.25	10.5	8.54	49.59	7.0	6.75	4.1	1.75	19.9	−6.5	−1.0	3.8	17.1	44.8	51.8	53.7	77.4	26.37
1913	16.8	9.84	8.85	10.9	9.30	50.35	8.2	7.35	5.2	2.8	19.8	−8.5	−2.6	4.0	16.9	47.9	54.3	57.0	77.3	26.45
1914	16.3	9.41	8.5	10.5	9.27	50.39	8.3	7.70	5.3	3.1	20.1	−9.9	−3.3	3.5	17.3	47.0	51.3	55.4	76.4	------
1915	16.5	9.60	8.7	10.4	8.57	48.84	8.0	5.35	2.5	0.75	20.5	−7.9	−0.8	3.5	17.8	46.6	52.6	53.7	76.2	------
1916	17.3	9.54	9.7	10.4	9.18	49.13	8.5	6.75	4.2	2.65	20.8	−7.0	−0.1	3.7	17.7	46.0	51.3	53.5	76.7	------
1917	16.8	8.81	8.75	9.3	8.24	47.04	7.6	5.75	3.8	1.4	20.2	−8.0	−0.1	2.7	16.8	43.2	49.8	50.4	76.3	------
1918	------	9.72	9.3	10.5	9.25	49.68	8.0	6.9	4.6	3.2	20.6	−10.2	−2.9	3.0	17.2	46.7	52.2	53.6	77.4	------
1919	------	9.38	8.35	9.9	8.06	47.94	7.2	5.75	3.9	1.9	20.6	−8.1	−0.5	2.1	17.3	47.5	52.8	54.4	77.3	------

A=South Italy (averages of the 3 stations: Naples, Lecce, Palermo).
B=Geneva (Switzerland).
C=Austria (averages of the 2 stations: Vienna and Kremsmünster).
D=Paris (France).
E=Germany (averages of the 10 stations: Königsberg, Berlin, Hamburg, Breslau, Leipzig, Münster i. w., Bamberg, Frankfurt a. m., Munich, Karlsruhe).
F=England (averages of the 8 stations: York, Cheadle, Rothamsted, Oxford, London, Marlborough, Ventnor, Plymouth).
G=Warsaw (Poland).
H=South Norway (averages of the 2 stations: Christiania and Bergen).
J=Helsingfors (Finland).
K=North Norway (averages of the 2 stations: Bodö and Alten).
L=Abbassia (Egypt).
M=Upernivik (Greenland).
N=Godthaab (Greenland).
O=Bernfjord (Iceland).
P=Ponta Delgada (Azores).
Q=Milwaukee, Wis.
R=New York, N. Y.
S=Cincinnati, Ohio.
T=Charleston, S. C.
U=Batavia (Java).

The numbers which are taken as the basis for these calculations are arranged in Table 1. For most places the same period 1876–1919 could be taken as a basis. For southern Italy, according to the material available, the period 1874–1917 had to be taken; for Ponta Delgada (Azores) the period 1887–1919; and for Batavia 1876–1908 were chosen. For each of these periods the phase of the 11-year sun-spot period was also determined in the manner indicated above, so that in each case the difference between the phases of the temperature period and sun-spot period could be calculated for the same period.

cides with the sun-spot minimum by no means in all regions of the Northern Hemisphere, but that—at least in the period 1876–1919—in the northern and continental parts of Europe, both maxima approximately coincide. A close study of Table 2 gives for the period 1876–1919 the following relations between the 11-year temperature period and the sun-spot period of the same duration.

(1) The temperature maximum coincides approximately with the sun-spot minimum only in the Tropics

[5] Monthly Weather Review, May, 1923, Vol. 51, p. 249.

(Batavia), and in the Subtropics (Abbassia, Ponta Delgada, Charleston); in the Tropics it falls rather before the minimum.

(2) In the Temperate Zone, except the western districts of the United States, the temperature maximum falls after the sun-spot minimum, and so, in general, the higher the latitude of the place, the later the temperature maximum. The increase in the phase shifting with the latitude is shown clearly in the following groups:

(*a*) Charleston, New York, Milwaukee;
(*b*) Godthaab, Upernivik;
(*c*) Abbassia, southern Italy, Germany;
(*d*) England, southern Norway, northern Norway.

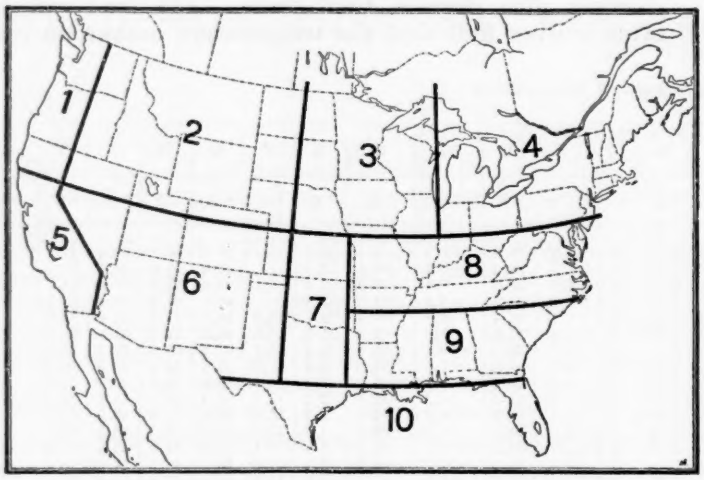

FIG. 1.—Subareas in the United States used in computation

TABLE 2.—*Phase differences of the 11-year temperature period*

District or station	Latitude	Amplitude in °C.	Phase	Difference: Phase of temperature period-phase of sun-spot cycle	Time of temperature maximum
A. *United States*			° ′	° ′	
1. District No. 1	40°–48°	0.205	40 44	−127 16	1⅗ years before sun-spot minimum.
2. District No. 2	40°–48°	0.231	12 11	−155 57	¾ year before sun-spot minimum.
3. District No. 3	40°–48°	0.428	341 11	+173 3	¼ year after sun-spot minimum.
4. District No. 4	40°–46°	0.384	347 57	+179 49	At time of sun-spot minimum.
5. District No. 5	32°–40°	0.157	72 6	−96 2	2½ years before sun-spot minimum.
6. District No. 6	30°–40°	0.222	16 5	−152 3	⅘ year before sun-spot minimum.
7. District No. 7	30°–40°	0.229	10 56	−157 12	¾ year before sun-spot minimum.
8. District No. 8	35°–40°	0.253	337 52	+169 44	⅖ year after sun-spot minimum.
9. District No. 9	30°–35°	0.065	16 50	−151 18	⅘ year before sun-spot minimum.
10. Milwaukee, Wis.	43° 2′	0.401	328 16	+160 8	⅗ year after sun-spot minimum.
11. New York, N. Y.	40° 43′	0.424	334 17	+166 9	⅖ year after sun-spot minimum.
12. Cincinnati, Ohio	39° 6′	0.425	328 55	+160 47	⅗ year after sun-spot minimum.
13. Charleston, S. C.	32° 47′	0.087	341 48	+173 40	¼ year after sun-spot minimum.
B. *Atlantic Ocean*					
14. Upernivik	72° 47′	0.418	277 45	+109 37	3¼ years before sun-spot maximum.
15. Godthaab	64° 10′	0.319	314 22	+146 14	4½ years before sun-spot maximum.
16. Bernfjord	64° 40′	0.085	215 56	+47 48	1½ years before sun-spot maximum.
17. Ponta Delgada	37° 45′	0.191	(161 56)	−173 31	¼ year before sun-spot minimum.
C. *Europe*					
18. South Italy	38°–41°	0.099	(276 59)	+145 51	4⅖ years before sun-spot maximum.
19. Geneva	46°–12′	0.107	166 23	−1 45	At time of sun-spot maximum.
20. Austria	48°	0.189	161 11	−6 57	⅕ year after sun-spot maximum.
21. Paris	48°–50′	0.105	224 14	+56 6	1¾ years before sun-spot maximum.
22. Germany	48°–54°	0.112	196 39	+28 31	⅘ year before sun-spot maximum.
23. England	50°–54°	0.025	283 6	+114 58	3½ years before sun-spot maximum.
24. Warsaw	52°–13′	0.164	176 21	+8 13	¼ year before sun-spot maximum.
25. South Norway	59°–60′	0.091	255 15	+87 7	2⅗ years before sun-spot maximum.
26. Helsingfors	60°–10′	0.126	98 39	−69 29	2 years after sun-spot maximum.
27. North Norway	67°–70°	0.158	124 12	−43 56	1⅗ years after sun-spot maximum.
D. *Africa*					
28. Abbassia	30° 5′	0.407	347 32	+179 24	At time of sun-spot minimum.
E. *Tropics*					
29. Batavia	−6° 11′	0.082	(22 54)	−159 2	⅗ year before sun-spot minimum.

(3) The greatest amplitude is shown by the temperature period in those regions in which the maximum coincides approximately with the minimum of the sun-spot period (Abbassia, Cincinnati, New York, Milwaukee, western and eastern sea regions of the United States).

(4) Besides the latitude of the places, the degree of their continental or oceanic positions is of importance for the phase shifting. In the oceans and in the western coast regions it is less. On the continents the temperature maximum is delayed from west to east. This is clearly shown in the following groups:

(*a*) Districts No. 1, No. 2, No. 3 of the United States;
(*b*) Districts No. 5, No. 6, No. 7, No. 8 of the United States;
(*c*) Paris, Germany, Austria;
(*d*) England, Germany, Warsaw;
(*e*) Southern Norway, Finland.

(5) An important difference in the phase exists between North America and Europe. In the United States of America the maximum of the 11-year temperature period generally lies nearer the sun-spot minimum; in Europe, however, it falls for the most part nearer the maximum of the sun-spot cycle. This is, of course, due in the first place to the fact that a great part of the United States is situated in the Subtropics, while Europe belongs almost wholly to the Temperate Zone and polar regions. The difference mentioned is therefore in the first place only a further proof that the 11-year temperature maximum is delayed with increasing latitude. At the same time, even with places of the same latitude, the maximum (or minimum) of the 11-year temperature period in North America seems actually to precede that of Europe. Thus, for example, in New York the maximum occurs two-fifths of a year after the sun-spot minimum; in southern Italy, however, one and one-tenth of a year after.

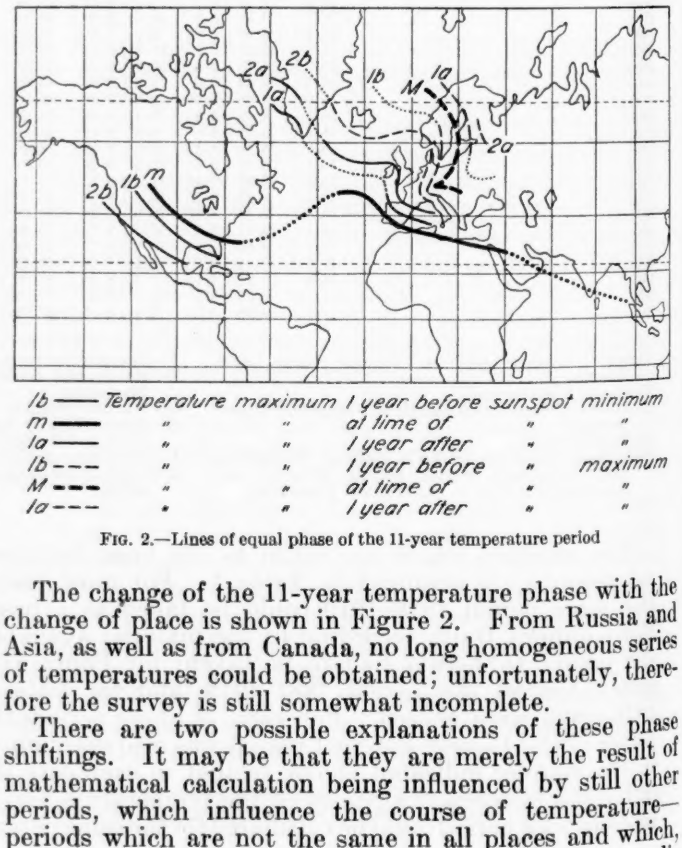

FIG. 2.—Lines of equal phase of the 11-year temperature period

The change of the 11-year temperature phase with the change of place is shown in Figure 2. From Russia and Asia, as well as from Canada, no long homogeneous series of temperatures could be obtained; unfortunately, therefore the survey is still somewhat incomplete.

There are two possible explanations of these phase shiftings. It may be that they are merely the result of mathematical calculation being influenced by still other periods, which influence the course of temperature—periods which are not the same in all places and which, as far as they are of like duration, are of different ampli-

tudes and phases in different places. The second possibility is that a physical importance may be attached to the phase shifting. The fact that extensive terrestrial regions show quite opposed phases of the 11-year temperature period, makes it probable that phase shifting is no mere result of mathematical calculation, but has physical causes. If one assumes with Abbot that in the 11-year period increased solar radiation corresponds to increased sun-spot activity, and if one further makes the assumption, credible after recent investigations, that the transparency of the atmosphere to solar radiation is diminished by increased solar activity, then one can imagine that the temperature maximum in high latitudes coincides approximately with the sun-spot maximum, for the reason that, at that time, radiation is stronger and the diminished transparency of dry polar air is of minor importance. In lower latitudes, however, the diminution in transparency, in consequence of the greater humidity of the atmosphere, overweighs the increase in radiation, so that here the heat minimum corresponds to the maximum of sun spots and vice versa. The idea that the disagreement between the 11-year temperature period in higher and lower latitudes is caused by the different quality of the air, is supported by the result shown in Figure 2, according to which, in regions which come chiefly under oceanic influence, the phase is also in higher latitudes similar to that in the Subtropics.

If now, however, the quality of the air, especially its humidity, is of influence on the time relation between sun spots and the 11-year temperature period, the latter, even if one disregards the inequality of the time periods maximum-minimum and minimum-maximum, can not at all be a simple function,

$$y=\frac{1}{2}\,a_0+\sin\left(\frac{2\pi}{11}\cdot\ t+\varphi\right)$$

but there must result, at least in the Temperate Zone, a different relation between sun spots and temperature in winter from that in summer. In order to test the truth of this, I have examined separately the temperatures of Germany[6] and New York[7] in the period 1876–1919. The result is as follows:

Germany, winter temperatures: Amplitude $(a)=0.144°C.$ phase $(\varphi)=147°\ 12'$ (maximum ⅔ years after sun-spot maximum). Summer temperatures: $a=0.060°C.$ $\varphi=309°\ 34'$ (maximum 4⅓ years before sun-spot maximum).

New York, N. Y., winter temperatures: $a=0.720°C.$ $\varphi=330°\ 38'$ (½ year after sun-spot minimum). Summer temperatures: $a=0.314°C.$ $\varphi=12°\ 20'$ (¾ years before sun-spot minimum).

In Germany therefore, the 11-year temperature period has actually, in winter and summer temperatures, almost opposed phases; in winter, the phase corresponds to the type of higher latitudes, in summer, almost to the tropical or oceanic one. In New York also the maximum of temperature in winter occurs distinctly later than in summer, but the difference, corresponding with its more southerly and coast situation, is of course only slight. In Germany, as well as in New York, in consequence of the greater mean variability of winter temperatures, the amplitude of the 11-year period is greater in winter, so that the phase of the annual means is nearer to that of winter temperatures. To summarize, it can be stated that the different quality of the atmosphere in the Tropics, over the ocean, in the summer of the Temperate Zone on the one hand, and in the Polar Regions, over the continent, in the winter of the Temperate Zone on the other hand, seems to exercise a determining influence on the relation of the 11-year period of temperature to the sun-spot period.

TABLE 3.—*Mean amplitudes, r, in °C. for different periods*

Period (T)	Greenland [a]	Iceland [b]	Geneva [c]	Germany [d]	Abbassia [e]	United States, 9 [f]
36-year	0. 41	*0. 44*	*0. 38*	*0. 42*	*0. 56*	0. 06
18-year	0. 21	*0. 34*	*0. 18*	*0. 30*	0. 20	0. 15
12-year	0. 43	0. 06	0. 01	0. 07	0. 21	0. 16
11-year	0. 37	0. 19	0. 06	0. 16	0. 21	0. 20
10-year	0. 34	0. 15	0. 10	0. 19	0. 21	0. 22
9-year	0. 34	0. 06	0. 11	0. 10	0. 15	0. 19
8-year	0. 40	0. 23	0. 11	9. 11	0. 14	0. 13
7.2-year	0. 43	0. 14	0. 13	*0. 25*	0. 12	0. 15
6-year	0. 18	0. 27	*0. 20*	0. 19	0. 07	0. 13
5.1-year	0. 25	*0. 40*	0. 07	0. 17	*0. 25*	0. 11
4.5-year	0. 08	*0. 29*	*0. 16*	0. 09	0. 20	0. 15
4-year	*0. 61*	0. 24	0. 14	0. 16	0. 07	0. 13
3.6-year	0. 11	*0. 40*	0. 11	0. 17	0. 15	0. 10
3.3-year	*0. 54*	0. 20	0. 11	0. 19	0. 15	0. 12
3.0-year	0. 16	0. 13	0. 09	0. 09	0. 10	0. 14
2.8-year	0. 17	0. 06	0. 07	0. 11	0. 07	0. 11
2.6-year	0. 29	0. 02	0. 08	0. 12	0. 02	0. 16
2.4-year	*0. 60*	*0. 30*	0. 07	*0. 23*	0. 14	0. 16
2.25-year	0. 44	0. 10	*0. 16*	0. 15	0. 10	0. 14
2.1-year	0. 12	0. 15	0. 05	0. 14	0. 09	0. 11
$r^1=$	0. 34	0. 19	0. 107	0. 15	0. 14	0. 15

$$r^1=\left(\int_{2^1}^{1^2} r.dT\right):9.9$$

The italicized amplitudes are greater than $1.5 > r^1$.

[a] Upernivik and Godthaab, 1884–1919.
[b] Berufjord, 1884–1919.
[c] Switzerland, 1847–1918.
[d] 10 stations, 1884–1919.
[e] Egypt, 1884–1919.
[f] District No. 9 of United States, 1884–1919.

In conclusion, it may be pointed out that only on a small part of the earth's surface has the 11-year temperature period an amplitude worthy of mention. As already stated, it is greatest in the Subtropics, in the North American lake district and on the west coast of Greenland; but even in the Subtropics (e. g., Charleston, S. C.), it in places almost completely vanishes. The large amplitude on the west coast of Greenland is evidently connected with the fact that, in relation to the high latitude of Greenland, the phase shows here a strong approach to the tropical type. It is urgently necessary to express a warning against the overestimation of the 11-year period of temperature, or even, as has already unfortunately been done, to build up on this periodicity alone a forecast of the character of the temperature of coming years. In Table 3 the result of several investigations of different series of temperature observations which have been carried out according to the method of the periodogram-analysis[8] is shown. From this it can be seen that the 11-year period of temperature in relation to other periods falls considerably into the background everywhere.[9]

[6] Mitteilungen der Wetter- und Sonnenwarte, St. Blasien, Heft 2, p. 14.
[7] Compiled from "Annual Meteor. Summary, 1921, with comparative data of N. Y., p. 9.

[8] Cf. Mitteilungen der Wetter- und Sonnenwarte St. Blasien, Heft 2, p. 20.
[9] See also for a similar conclusion with respect to rainfall: Alter, Dinsmore, Application of Schuster's Periodogram to Long Rainfall Records, beginning 1748. Mo. Weather Rev., Oct., 1924, **52**: 479–483.—B. M. V.

RADIATION AND POLARIZATION MEASUREMENTS DURING THE SOLAR ECLIPSE OF APRIL 8, 1921, AT DAVOS

By C. DORNO

The following note was sent to the Solar Radiation Investigations Section of the Weather Bureau by Doctor Dorno, with the comment that "The interest which was taken in the solar eclipse of the 24th of January, 1925, was so great in the United States that perhaps the hitherto unpublished observations conducted here on that of the 8th of April, 1921, will also be found worth attention." Slight changes have been made in the text, the original figures of course remaining unaltered.

Commencement of the eclipse, $8^h.175$

Maximum obscuration, $9^h.430$

End of the eclipse, $10^h.783$

Maximum obscuration, 0.738 solar diameter, or 0.663 solar area.

Cloudiness, during first half of eclipse 3–4 Fr.-Cu.; later 0.

Radiation.—At the time of maximum obscuration, a decrease was found as follows:

	Per cent
In the total intensity	73. 0
In the intensity of the red rays (measured with Michelson's actinometer in single readings)	70. 8
In the intensity of the ultra-violet (measured with cadmium cell)	77. 4
In the total intensity of sun plus sky (registered with Angström's pyranometer)	66. 8

The decrease and increase occurred unsymmetrically with the chief phase as follows:

In total intensity	decrease slower than increase;
In red intensity	decrease slower than increase;
In ultra-violet intensity	decrease more rapid than increase;
In sun plus sky intensity	decrease more rapid than increase.

The percentage of decrease of radiation is greater than the percentage of obscured surface, for the reason that at the maximum phase a relatively large part of the unobscured solar surface was near the solar margin, and only a small part consisted of the strongly radiating center of the sun's disk. The decrease of brightness from the center to the margin of the solar disk is greater for ultra-violet than for red; therefore, the measurements give a greater decrease of radiation in the ultra-violet than in the red. From the distribution of brightness over the solar disk for wave length 0.644 (red) determined by C. G. Abbot[1] and for ultra-violet, 0.320 (approximate optic center of gravity of cadmium cell) by Schwarzschild and Villiger,[2] a loss of radiation is calculated from the surface obscuration of 74.7 per cent of red, and 81 per cent for ultra-violet, i. e., 3.9 per cent for red and 3.6 per cent for ultra-violet more than found. The diffraction of rays round the edge of the obscuring disk of the moon necessitates a difference in the direction measured, and this must be somewhat greater for red than for ultra-violet, as the diffracted light arises from the marginal zones which are relatively rich in red.

According to the visual observations made, the velocity of travel of the shadow from 25 minutes before until 25 minutes after the maximum appears to have been approximately the same, and the total duration of the increase is about seven minutes longer than that of the decrease. Both these observations are in agreement with the variations in the ultra-violet radiation which, owing to the quartz optical system employed, was exclusively of solar origin. On the other hand, in conformity with the construction of Michelson's actinometer, the values for the total and red radiation include a zone of the sky which extends to about 5 degrees around the sun; therefore their radiation values exhibit slightly different changes.

Polarization.—The amount of polarization of the zenith undoubtedly increased during the eclipse, as a comparison with the normal spring values belonging to the corresponding solar altitudes proves. The course of the Babinet point is not distinct; during the first half of the eclipse it appeared to approach the sun, while its course during the second half casts doubt upon this conclusion.

Meteorological elements.—Temperatures measured with Assman's aspiration psychrometer distinctly show a fall of the wet bulb as well as of the dry bulb thermometers, which reaches a maximum at the time of maximum eclipse. The relative humidity derived from these temperatures shows no reversion, although an interruption of the normal daily decrease sets in shortly after the maximum eclipse phase. The atmospheric pressure fell slowly and continuously from morning until noon, the total fall amounting to 0.8 mm.

[1] Annals of the Astrophysical Observatory, III, p. 157.

[2] Physikalische Zeitschrift, 1905, p. 742.

SEASONAL PRECIPITATION IN CALIFORNIA AND ITS VARIABILITY

By B. M. VARNEY

PART II

V. MEAN SEASONAL DEPARTURES FROM MEAN SEASONAL RAINFALL IN CALIFORNIA

1. *Selection of stations as a basis for mapping.* The mapping and discussion of the mean seasonal departures have been based on the records of the 82 stations which at the end of the 1919–20 season had 25 seasons of record. The reasons for thus limiting the basis for the treatment of this phase of the subject are three: First, it is preferable to compute departures on the basis of means derived from the actual number of seasonal totals available for the station in question, and not on adjusted means. Second, means based on short periods may not be at all representative of the true conditions. Third, the small number of departures available in the short records make any computation of mean departures from seasonal averages in terms of percentage of those averages highly illusory.

The resulting restriction of the number of records that can justifiably be used leads to unsatisfactory distribution of the stations for mapping purposes. The situation is made clear by reference to Figures 1 (see part 1 of this paper, in REVIEW for April, 1925) and 5, the first of which, together with the alphabetical and numerical lists of stations in Table 3 (in part I of this paper), forms a guide to the stations used, and the second of which shows the distribution of percentage departures for those stations. Points that will be noted in regard to station distribution are: First, the high concentration of stations in the north central part of the State, and the moderate concentration in southern California; second, the very

cattered distribution in the north, in the deserts, in the Coast Ranges, and along the coast, except where the last two regions are affected by the concentration in the north central area; third, the fact that the Sacramento Valley is much more adequately represented than the San Joaquin.

In spite of this admittedly poor distribution of stations, certain broad facts may be deduced from the map (fig. 5) and from the dot chart (fig. 6). These will now be briefly noted.

2. *Relation of departures to altitude.*—Referring first to the chart, the departures in percentages of the mean seasonal totals of rainfall at each of the 82 stations are there plotted with reference to the altitudes of their occurrence, ordinates representing altitudes and abscissae the amounts of percentage departure. The most striking facts shown are the concentration of the departures largely within the limits of 20 and 30 per cent, and the lack of clear relation of the departure to altitude. Table 8 serves to emphasize these facts. The first column

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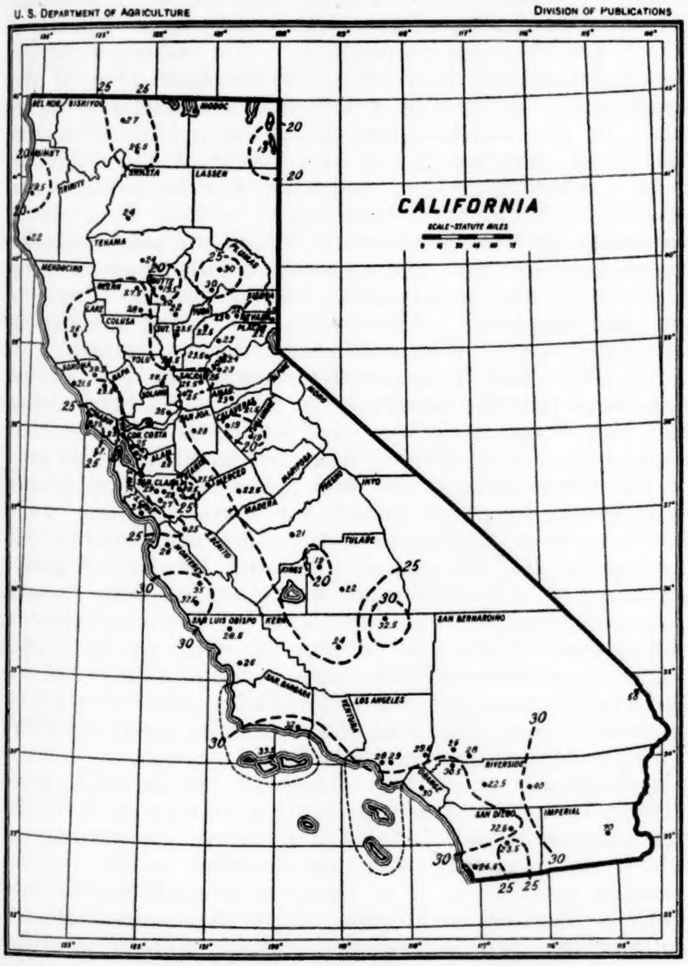

FIG. 5.—Average seasonal departures of precipitation in percentages of the seasonal average rainfall at stations having records of not less than 25 seasons ending 1919–20

divides the range of altitudes into thousand foot zones, the second give the number of stations within each zone, the third the spread between the greatest and least departures within each zone, and the fourth the mean of the departures within the zone.

3. *Discussion of the areal distribution of departures.*—The range of departures is not large. Nevertheless it is probably more significant than its size might suggest, on account of the wide differences in mean seasonal rainfall through which this moderate range of departures runs. That is to say, from the point of view of the influence of rainfall on vegetation, a mean departure of 25 per cent from a rainfall of 40 inches may mean quite different consequences from the same mean departure from a rainfall of 20 inches. In the first instance, minus departures rarely affect yields to a serious extent; in the second they may easily do so. This aspect of rainfall is of little importance in irrigated areas which are well

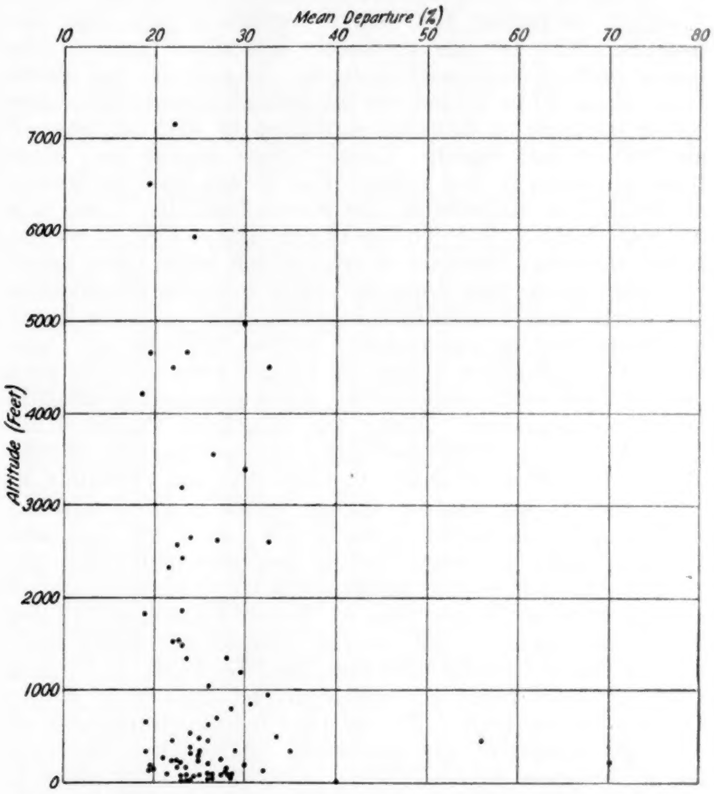

FIG. 6.—Relation between altitude and the average seasonal departures (in percentages of the seasonal average rainfall) for stations having not less than 25 seasons of record ending 1919–20

supplied with facilities for water storage; but on areas not well supplied and on nonirrigated lands, it may become of the greatest importance. This is particularly the case in the pasture region of the Coast Ranges where the tendency to a somewhat greater variability than obtains in the central agricultural region of the State is one cause of the occasional serious deficiency in the crop of wild grasses which results in great losses of cattle in the years of large minus departures.

TABLE 8.—*The relation between altitude and mean departures of seasonal precipitation from the average*

Altitude zones	Number of stations	Difference between greatest and least departures (per cent)	Mean of all departures (per cent)
Feet			
0–1,000	52	16	25.8
0–1,000	[1] 52+3	51	27.2
1,000–2,000	9	11	24.1
2,000–3,000	6	12	25.1
3,000–4,000	3	7	26.5
4,000–5,000	5	15	23.2
5,000–6,000	2	8	26.0
6,000–7,000	1		19.5
7,000–8,000	1		22.0

[1] Desert stations.

Within the small range of departures certain regions of the State stand out with considerable clearness, though in interpreting the map it should be borne in mind that except in regions where stations are close together, the location of the lines is highly provisional.

(*a*) *The region east of the Sacramento and San Joaquin Rivers.*—In general it may be said that so far as the stations indicate, the northeastern part of the Sacramento Valley, the eastern half of the San Joaquin Valley, and the whole of the Sierra Nevada (except locally in Plumas County) including the entire foothill region, has departures that average distinctly less than those of the major part of the Coast Ranges. As pointed out above there seems to be little basis for believing that departures either increase or decrease significantly with increase of altitude in this region. Locally they appear to. Thus from Stockton in the Valley close to sea level to Sonora at 1,825 feet altitude in the Sierra foothills, there is a decrease from 23 per cent to 19 per cent. This, however, is but the same decrease as that which takes place longitudinally in the San Joaquin Valley between Stockton in the north and Visalia in the south. On the other hand, three stations at successively higher altitudes in Calaveras County show values of 19 per cent, 22 per cent and 21.5 per cent, respectively, a net change too small to be of consequence. Along the Southern Pacific Railroad, Auburn at 1,360 feet has a mean departure of 23.5 per cent, Colfax at 2,421 feet 23 per cent, Summit at 7,017 feet 22 per cent, a change which is quite without significance. Between Nevada City at 2,580 feet and Fordyce Dam at 6,500 feet, a decrease from 22.5 per cent to 19.5 per cent is interrupted by the occurrence of a departure of 23 per cent at North Bloomfield (3,200 feet). Between Oroville at the base of the Sierra foothills in Butte County (250 feet) and La Porte in Plumas County (5,000 feet), the departure changes from 22 per cent to 30 per cent. No stations intermediate exist to show the nature of the transition. Altogether, the case for a decrease of variability with increasing altitude seems about as good as for an increase, and vice versa.

(*b*) *Comparison between the Sacramento and San Joaquin Valleys.*—The mean of all departures in the Sacramento Valley (14 in number) is 25 per cent, a departure appreciably higher than the mean of 22.9 for the seven stations in the San Joaquin. The latter mean is increased, moreover, by the value of 27.5 for Newman on the west side of the valley, that station having a departure which is characteristic of those in that part of the Coast Ranges lying to the west of the valley, apparently due to its nearness to the Coast Ranges. This variation from the typical valley condition is in accord with that seen in the western part of the Sacramento Valley throughout its length. In fact, if we take the mean of the seven stations in the eastern Sacramento Valley (east of the Sacramento River), we find it to be 23.1 per cent, or to all intents and purposes identical with that of the six stations in the San Joaquin, excluding Newman. The mean of the six west-side stations is 27.8 per cent (excluding Knight's Landing on the west bank of the river, which has a mean departure of 24.5 per cent, distinctly intermediate between those of the eastern and western areas). This mean of the west-side stations is essentially the same as that at Newman, the one station available for the western San Joaquin. For the whole Interior Valley, then, it may be said that departures average about 5 per cent greater in the western than in the eastern parts, and that longitudinally on either side the differences between the northwest end and the southeast are so small as to be without importance.

The extreme ends of the valley show perhaps the beginning of a transition to conditions which seem to be characteristically different from those in the eastern part of it. On the north there is a tendency toward increasing departures as one goes into the hill and mountain country. On the south, Bakersfield has a slightly higher mean departure than any of the east-side valley stations, 24 per cent, and Kernville at 2,600 feet altitude in the Tehachapi Range with a mean departure of 32.5 per cent shows an increase well above the valley stations, due probably either to increased elevation or to the fact that it is situated in the fringe of the great southeastern desert area of the State.

(*c*) *The southeastern desert.*—The southeastern desert has departures greater than any other region in California, culminating in the extraordinary value of 70 per cent of the mean seasonal rainfall at Sterling in the Imperial Valley. Needles, on the Colorado River, and Indio some 20 miles northwest of the Salton Sea, have departures which are only less remarkable. The statement of the mean departures, however, conveys little idea of the conditions. It may be noted that the extreme departures in this southeastern desert have little effect on agriculture because this is exclusively of the irrigation type. When there is an influence it is the adverse one of too much moisture, resulting in certain ill effects of dampness on commercial crops which are here normally exposed to extreme atmospheric dryness, and resulting occasionally also in damage to crops in process of harvesting and shipment. The writer has heard farmers in this region say: "We would rather it never rained."

(*d*) *The Coast Ranges and the coast.*—It was pointed out above that the departures in the western Sacramento and San Joaquin Valleys were similar to those in that part of the Coast Ranges lying to the west. This area of the Coast Ranges lies within the isogram of 25 per cent mean departure except for a coastal strip in the north along which the departures are considerably less. Averaging the 12 stations inclosed by this isogram, including 2 of over 30 per cent in Monterey County and excluding the 18.5 per cent for Mount Hamilton (for a reason that will be pointed out), we have 28.2 per cent, or essentially the same value as that found for the western part of the Interior Valley, and some 5 to 6 per cent higher than that of the eastern Interior Valley. There is little evidence of significant increase or decrease longitudinally in either direction within this area. Mount Hamilton clearly presents a divergence from the general condition. In this divergence, on account of which its departure was not included in the general average just given, it is comparable with San Jacinto Peak in southern California. Both mountains form the culminating and somewhat isolated summits of their respective highlands. It may be that their notably smaller average departures as compared with the surrounding lower country are in accordance with a law the existence of which could be demonstrated if we had enough records from similarly isolated peaks distributed throughout the State.

A relatively narrow zone along the outer coast from the Oregon line to Monterey Bay has, so far as indicated, departures somewhat smaller than those of the major part of the Coast Ranges adjacent. From the bay southeastward, however, departures are consistently

higher than in the north, varying mostly within 3 per cent either way from 30 per cent of the mean seasonal rainfall. San Diego shows but 26.5 per cent.

(e) *Relation of mean seasonal departures to mean seasonal rainfall.*—An inspection of the map does not lead to the conclusion that mean percentage departures tend to vary consistently either directly or inversely with the amount of the mean seasonal rainfall. Departures in the San Joaquin Valley with its rainfalls of 5 to 10 inches, appear to be of the same order as those of the northwest coast where the rainfall is three to ten or more times as great. The southeastern desert shows departures of 40 to 70 per cent (three stations), while the northeastern semiarid region shows a departure of 19 per cent (one station). Stations along the coastal strip of southern California with rainfalls of 10 to 20 inches have mean departures approximating 30 per cent, while the same departures occur in Plumas County in the northern Sierra Nevada with rainfalls of 40 to 75 inches. Other comparisons leading to the same conclusion are evident from the map.

(f) *Summary.*—We may conclude from the above discussion that—

1. The eastern part of the Interior Valley and the Sierra in general show less variability than the western part of the valley and the Coast Ranges.
2. There appears to be no consistent increase or decrease of variability with increase of altitude in the Sierra.
3. The departures in the eastern part of the Interior Valley tend to increase toward the mountain or desert country north and south of them respectively.
4. The departures of the southeastern desert region are the most extreme in the State.
5. Along a narrow coastal zone, departures appear to be distinctly less in the northern half of the coast than in the southern.
6. The departures in the Coast Ranges average somewhat higher than those of the eastern Interior Valley and of the northern coastal zone, and do not change significantly from north to south along the ranges.
7. While there does not appear to be any strong relation between the amounts of mean percentage departure and the amount of the average seasonal rainfall, nor any clear evidence of a gradual increase in variability with decreasing latitude, nevertheless, speaking very broadly, the agricultural region of southern California west of the desert does show a somewhat greater variability than the major agricultural regions north of latitude 35 degrees.

VI. FREQUENCIES OF RAINFALLS OF CERTAIN AMOUNTS AT CALIFORNIA STATIONS

1. *Method of presenting rainfall frequencies in this section.*—For the purpose of depicting this aspect of California rainfall, it has been thought best to confine the graphic material to such as could be presented in diagram form (as distinguished from map form), and the examples to stations having 40 years of record or more. In the frequency computations which form the basis of the polygons in Figure 7, use has been made of the full length of the record in each case, and percentage frequencies (x) arrived at through the proportion:

$$\frac{\text{Actual frequency of stated seasonal amounts}}{\text{Number of seasons of record}} = \frac{x}{100\,\text{seasons}}.$$

By extending the records of a few stations through the season 1922–23 it has been possible to include a total of 43 stations, a number which allows a fair distribution areally, and a representation of each major topographic region of the State. In setting apart the different regions no attempt has been made to determine exact physiographic boundaries. This is rendered unnecessary for the present purpose by the wide dispersal of the stations. From this point of view the Sierra Nevada is perfectly distinct from the Interior Valley, the southeastern desert from that part of southern California west of the desert, etc. Frequencies have been computed and frequency polygons constructed, for seven groups of stations, as follows:

1. *Coast Range group.*—Nine stations, arranged in order of decreasing latitude.
2. *Sierra Nevada group.*—Ten stations divided into two subgroups separated by the contour of 2,600 feet, each subgroup comprising five stations arranged in order of increasing altitude.
3. *Central Valley group.*—Twelve stations arranged in order of decreasing latitude.
4. *Coastal group.*—Four stations on the outer coast, as distinguished from those in group 1, and arranged in order of decreasing latitude.
5. *Northern Hill and Mountain group.*—Two stations.
6. *Southern California group.*—Four stations arranged in order of decreasing latitude.
7. *Southeastern Desert group.*—Two stations.

2. *Discussion of the frequency polygons.*—In the polygons each tenth of an inch horizontally represents 5 inches of rainfall and vertically 2 per cent of frequency. Thus each polygon shows percentage frequency of seasonal total rainfalls by 5-inch groups, the number of columns being an approximate measure of the range of seasonal amounts which may be expected in 100 years, while a rough indication of the degree of variability of the rainfall is afforded by the symmetrical or other arrangement of the columns on either side of that which represents the group of maximum frequency. In illustration of this last point the figures for Emigrant Gap (upper Sierra Nevada group) and for Placerville (lower Sierra Nevada group) may be compared. Emigrant Gap experiences seasonal rainfalls ranging through 16 groups from the 15–20 inch to the 90–95 inch. However, 85 per cent of the seasonal totals range through the 40 inches between 30 and 70 inches. Placerville experiences rainfalls ranging through 12 groups from the 20–25 inch to the 75–80 inch, but 88 per cent of the seasonal totals range through the 35 inches between 25 and 60 inches. In other words, the range of seasonal totals, leaving out of account the very large and the very small totals, is roughly the same at both stations. But inspection of their respective polygons shows striking differences in the distribution of frequencies. For Emigrant Gap, barring the 15 per cent of very large or very small totals, the remainder is composed of considerable frequencies of widely different rainfall amounts. Thus, seasonal totals of 30–35, 55–60, and 65–70 inches are equally frequent (12.5 per cent each). The most frequent total, that of 50–55 inches, is only 2.5 per cent more frequent than the totals just named. In contrast to this condition, at Placerville the group of most frequent occurrence is the 35–40 inch, with 17 per cent, the group next above and below having 14 per cent, the next above and below these, respectively, 12 per cent—a strongly symmetrical distribution. Hence at Placerville the frequencies decline consistently as the totals become both greater than and less than the most frequent total, while at Emigrant

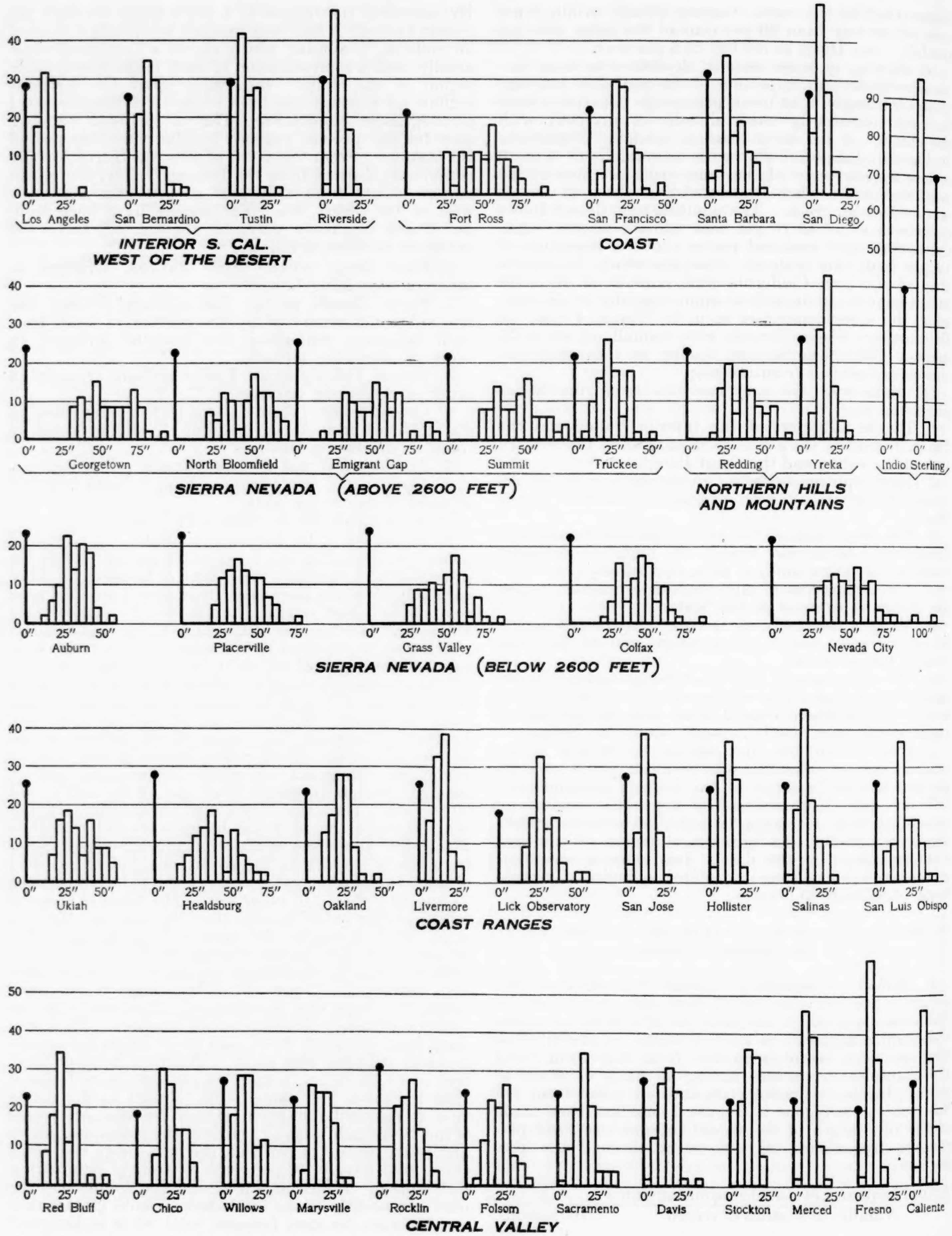

FIG. 7.—Frequencies of rainfall by 5-inch intervals for groups of stations having records of 40 seasons or over, the period covering the full record in each case and usually ending 1919–20

Gap both the very large and the very small totals are of about equally frequent occurrence.

3. *Frequency of rainfall percentages by 5-inch groups versus mean seasonal rainfall departures in percentages of the seasonal average rainfall.*—Combined with the frequency polygons of Figure 7 are graphic representations of the mean departures at the same stations. The dots at the tops of the heavy vertical lines erected at the zero point of the rainfall scale for each polygon indicate the mean seasonal departure in percentage of the average seasonal rainfall at the respective stations.

It is appropriate in this connection to call attention to the fact that the mean departures in percentages are not related to the range of the rainfall groups. That is to say, if we think of the changeableness of seasonal rainfalls in terms of the range of the actual amount recorded, then certain stations have a highly variable rainfall, as, for instance, Emigrant Gap or Nevada City. But if we think of it as expressed in terms of the mean departures in percentages of the seasonal average, then these stations have but moderate changes from season to season in comparison with many other stations in California. An extreme case, and therefore a useful one for illustration, is that of Sterling, in the Imperial Valley. Here a minimum variability in terms of spread of rainfall by 5-inch groups is coincident with a maximum variability in terms of percentage departures from the seasonal average.

4. *Relation between the magnitude of the rainfall averages and the number of rainfall groups.*—By way of contrast to the above, it may be noted that, broadly speaking, diminishing means of rainfall connote diminishing ranges of the individual seasonal amounts. To show approximately what this relation is, the dot chart of Figure 8 has been prepared, in which the number of rainfall groups at the 40-year stations used above are given as abscissae, and the mean rainfalls for 25 seasons at these stations as ordinates. The general rule, obviously, is true only within rather wide limits. For a given spread of rainfall groups there is a rather wide range in the seasonal mean rainfalls. Thus the stations having a spread through nine groups show rainfalls that vary from 15 to 37 inches. Likewise, for rainfalls of the same general magnitudes there are rather wide differences in the spread of the groups. Thus, the means which approximate 15 inches occur at stations which have a spread of the groups varying from 5 to 9.

It is probably true that neither one of these ways of expressing the vagaries of seasonal rainfall at a given place is adequate from all points of view. To the irrigation engineer, both the frequencies of stated amounts and the mean departures are of great significance, since his problem is partly one of the storage capacity of reservoirs in relation to successions of "wet" and "dry" years. Still more important is the distribution in time of the occurrences on which the frequency computations are based. The relation of this distribution to mean departures, the distribution being stated in terms of mean seasonal variability, will be briefly discussed in the section on "The Mean Variability of Precipitation."

5. *Agriculture and the frequency distribution of rainfall.*—A discussion of the relations between the facts shown by Figure 8 (dot chart) and the influences on agriculture of the frequency distribution of the seasonal rainfalls about the means is beyond the scope of this paper. The problem of what constitutes a deficient or an excessive seasonal rainfall is clearly a highly complex one. So far as the writer is aware, there is no discussion of it in print, except in the form of isolated and unrelated instances of the relation between a given crop and rainfall. It may be noted that beans in southern California are grown commercially year after year without irrigation under rainfalls of about 10 inches. Therefore for them 10 inches is not a deficient rainfall. The same amount in the nonirrigation decidious fruit belt of the Sierra foothills would be ruinous. Adequate discussion of the problem would deal with the infinitely variable relations between the water requirements of crop plants and precipitation, evaporation, soils, etc. From the point of view of nonirrigation agriculture, frequencies of occurrence of given amounts and the range within which they vary are likely to be more important than mean departures.

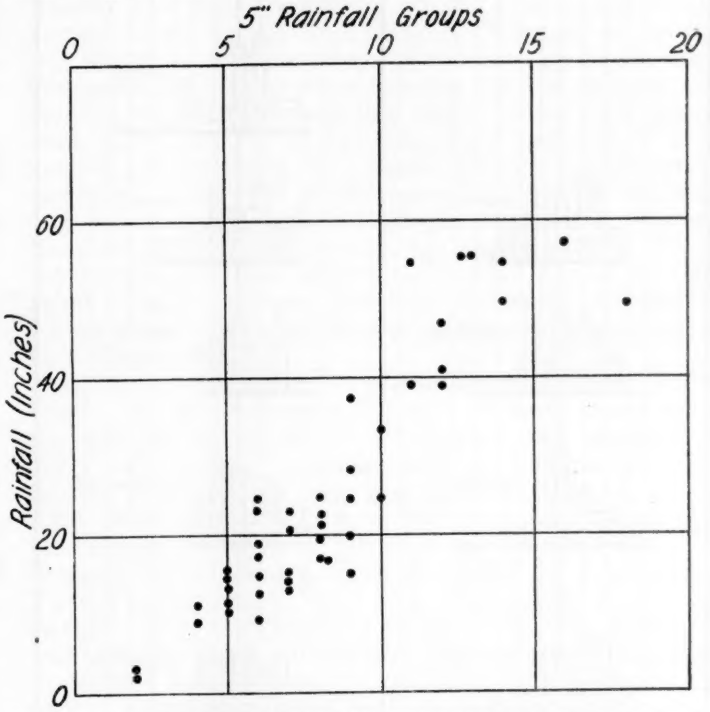

FIG. 8.—Relation between the numbers of 5-inch rainfall intervals (40 seasons or more) and the averages of rainfall (uniform period of 25 seasons)

In order that a certain amount of detailed information may be available regarding the frequencies of occurrence of given seasonal amounts of rainfall in terms of the percentages of the average amounts, the frequency polygons of Figure 9 have been prepared. The data from 42 stations having records of 40 seasons or more have been used. In the figure the percentages of normal are divided into 10-per cent groups, a 95–100 per cent group being that of least departure from the average, and the groups being arranged in order toward the lower and higher percentages.

The procedure in arriving at the percentages indicated was as follows: First the frequency of each percentage group for the whole period of each group was found. These records being of various lengths, with a mean length approximating 50 seasons, the actual frequencies were converted to the 50-season basis by proportion. This was done so that the polygons for the individual stations, besides indicating the conditions for that station, would also be comparable with the polygons for all the other stations of the list. This comparability is not perfect, however. In the conversion, fractional frequencies had to be discarded in the process of stating the frequency of a given percentage to the nearest whole number. Hence it is that a count of the blocks in many of the polygons would show numbers somewhat above or

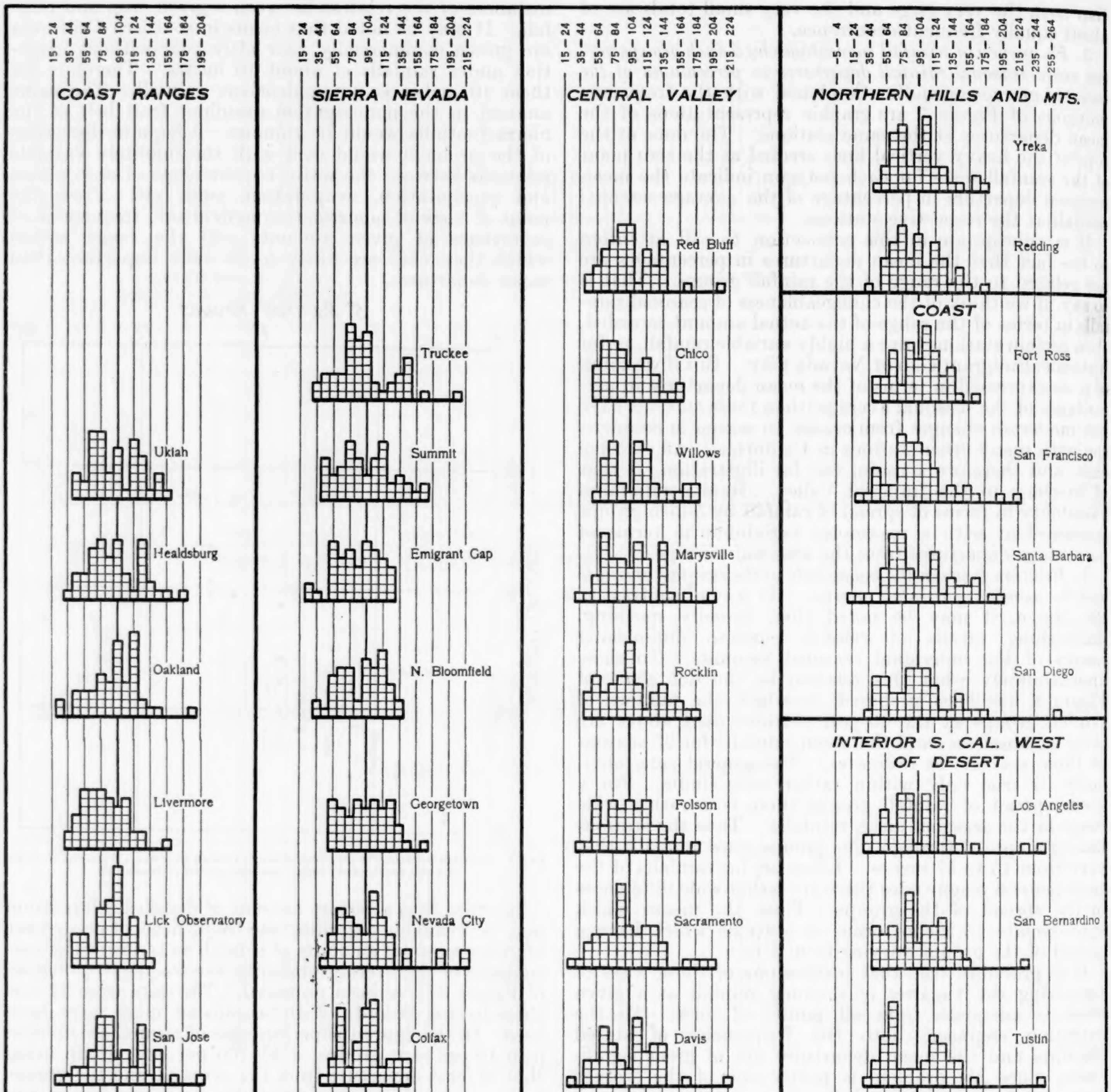

FIG. 9.—Frequency distribution of seasonal rainfall about the average, at 42 stations having not less than 40 seasons of record ending 1919-20. The frequencies are adjusted to a uniform 50-year period. The rainfalls are expressed in groups of percentage departures from the normal. From the "normal" group at top of figure, a heavy vertical line passes through the "normal" group in each column of polygons

below 50. It is believed this feature does not seriously impair the value of the figure.

It is not the intention to go into a complete discussion of the multitude of facts revealed by the polygons. Reference to their outstanding features as a whole would include mention of the extraordinary differences in the distribution of the frequencies, ranging from approximate symmetry about the modal frequency to complete lack of symmetry. Noticeable also is the rarity with which the most frequent seasonal rainfall coincides with the average rainfall (8 cases out of 42). The tendency is for this most frequent rainfall to lie considerably below the average—some 20 to 25 per cent, roughly speaking. This fact suggests that from some points of view a statement of the "average" rainfall of a place may be quite misleading. In those cases in which the frequencies are most symmetrically distributed about the mode, especially if this is accompanied by a rapid decrease of the frequencies on either side of it, a knowledge of what percentages are most frequent, next most frequent, etc., would undoubtedly give a more vivid and truer picture of the conditions.

Another aspect of the data for the same 42 stations is presented in Table 9. Therein are given, first, on the basis of the whole length of record at each station, the frequencies of departures within stated percentages of the average rainfall (either plus or minus) as adjusted to the uniform 50-year period; second, these frequencies converted into percentages frequencies, which in this case was very simply done by multiplying the adjusted frequencies by two.

TABLE 9.—*Frequencies in 50 seasons of departures (either plus or minus) within limiting percentages of the average seasonal rainfall at 42 stations having records of 40 seasons or more ending 1919–20, the frequencies being adjusted to the uniform 50-season basis*

Stations	Full length of record (seasons)	Limiting departures (per cents)				Percentage of cases			
		15	25	35	45	15	25	35	45
Ukiah	43	10	25	38	41	20	50	76	82
Healdsburg	43	15	23	36	41	30	46	72	82
Oakland	46	17	32	37	41	34	64	74	82
Livermore	49	17	26	35	42	34	52	70	84
Lick Observatory	42	24	37	41	46	48	74	82	92
San Jose	46	15	25	36	39	30	50	72	78
Hollister	46	15	26	35	40	30	52	70	80
Salinas	47	15	30	37	41	30	60	74	82
San Luis Obispo	51	16	29	32	39	32	58	64	78
Auburn	49	18	33	41	45	36	66	82	90
Placerville	40	21	31	39	44	42	62	78	88
Grass Valley	45	25	34	39	47	50	68	78	94
Colfax	50	24	28	40	46	48	56	80	92
Nevada City	56	18	30	41	45	36	60	82	90
Georgetown	47	17	25	36	45	34	50	72	90
North Bloomfield	42	15	29	39	46	30	58	78	92
Emigrant Gap	40	17	28	37	44	34	56	74	88
Summit	50	13	27	33	39	26	54	66	78
Truckee	50	17	27	32	38	34	54	64	76
Red Bluff	43	17	28	36	45	34	56	72	90
Chico	49	14	26	36	42	28	52	72	84
Willows	41	10	23	30	33	20	46	60	66
Marysville	49	16	26	34	43	32	52	68	86
Rocklin	47	18	23	29	38	36	46	58	76
Folsom	49	16	28	34	43	32	56	68	86
Sacramento	71	19	28	37	44	38	56	74	88
Davis	48	13	22	34	42	26	44	68	84
Stockton	53	18	27	36	43	36	54	72	86
Merced	48	19	28	36	39	38	56	72	78
Fresno	42	20	36	43	46	40	72	86	92
Yreka	43	17	28	38	42	34	56	76	86
Redding	45	14	28	38	43	28	56	76	86
Fort Ross	45	21	29	38	45	42	58	76	90
San Francisco	71	20	32	35	39	40	64	70	78
Santa Barbara	53	10	24	33	40	20	48	66	80
San Diego	70	18	25	29	35	36	50	58	70
Los Angeles	43	15	29	40	47	30	58	80	94
Tuskin	43	7	15	30	39	14	30	60	78
San Bernardino	50	17	24	35	41	34	48	70	82
Riverside	42	13	22	26	36	26	44	52	70
Indio	43	12	14	18	21	24	28	36	42
Sterling	42	3	17	20	21	6	34	40	42

This table in graphic form appears in Figure 10. In it the height of the column for a given limiting percentage departure from the seasonal average of precipitation represents the frequency (in per cent of the total number of cases) with which that limiting percentage occurs. Thus Ukiah (upper left corner of the figure) on the 50-season basis had in 20 per cent of the seasons, departures, either plus or minus, of 15 per cent or less; in 50 per cent of the seasons departures not over 25 per cent; in 76 per cent of the seasons not over 35 per cent either way from the average seasonal rainfall; and in 82 per cent of the seasons, departures not over 45 per cent.

A general interpretation of the columns for any station is as follows: The shorter the column under any limiting departure the greater are the frequencies left for representation by the other columns, either by one of the four shown, or by others beyond the limiting 45 per cent. Comparison of the extreme cases in the Los Angeles and Sterling graphs will make this clear. (See fourth group from top of sheet). At Los Angeles, departures of more than 45 per cent from the seasonal average are extremely rare (but 6 per cent of the seasons), while at Sterling they are extremely frequent (58 per cent of the seasons). Comparing Los Angeles with, for instance, Lick Observatory, one sees that departures beyond 45 per cent are about equally frequent, but that departures beyond 25 per cent are much commoner at Los Angeles than at Lick Observatory.

To give a regional arrangement of the graphs in Figure 10 the following scheme is used: Stations in the top line are in the Coast Ranges and arranged in order, left to right corresponding to the direction NW. to SE.; in the second line, Sierra stations stand, left to right, from lower stations on the west over the summit to Truckee in order of altitude; in the third line, left to right, are stations from NW. to SE. in the Interior Valley; in the fourth line, from the mountain and hill country of the north via the coast to southern California and into the desert; in the fifth line, a cross section of the State from San Francisco to Truckee. Lines joining the tops of columns for equal limiting departures are to guide the eye in making comparisons.

Much might be written on the details shown by the figure; the following points are perhaps of principal interest:

Top line.—The apparent regional change longitudinally in the Coast Ranges of the limiting departure of 15 per cent; the lack of system in the 25 per cent limiting departure; the strong contrast between Lick Observatory and all the other stations of the group, as pointed out in another connection.

Second line.—The shifts of frequency of the 15 and 25 per cent limiting departures with altitude across the Sierra.

Third line.—The contrast between Willows (a west-side valley station) and the east-side valley stations.

The striking rise of frequency of the 25, 35, and 45 per cent limiting departure between Merced and Fresno, suggesting a marked increase in the reliability of the rainfall from NW. to SE. in that region.

Fourth line.—The striking shifts in the frequencies of all departures between Los Angeles or Tustin near the coast into the desert.

Fifth line.—The suggestion, from the change in the heights of the 25, 35, and 45 per cent columns, that the frequencies of these departures may in some way be related to altitude of station and to the rainfall profile across the Sierra. It will be observed that the maximum

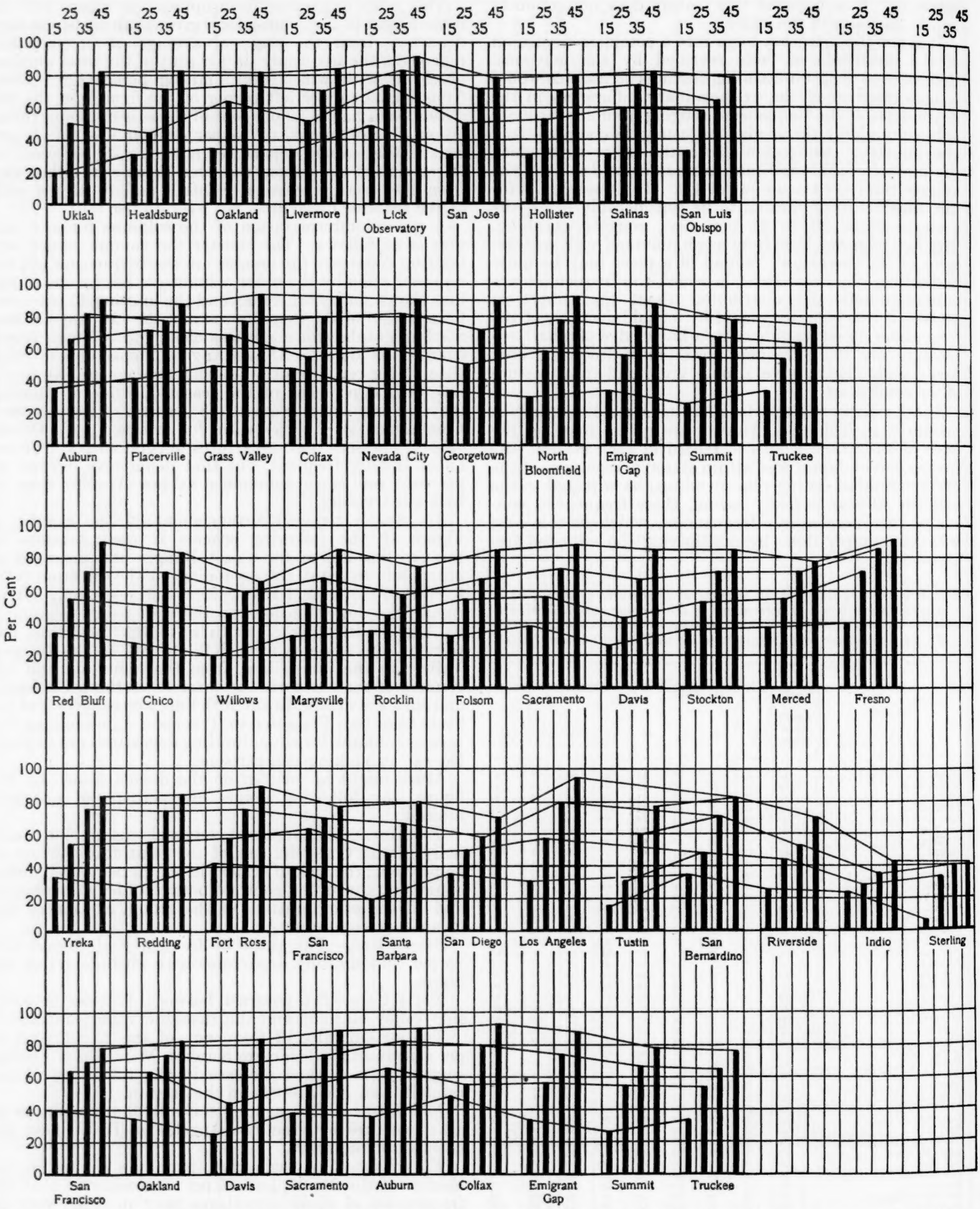

FIG. 10.—Frequencies (in percentages of total number of cases) of the seasonal totals of rainfall within 15, 25, 35, and 45 per cent of the seasonal average rainfall, at 42 stations having not less than 40 seasons of record ending 1919-20. Frequencies adjusted to a uniform 50-year period

frequencies of all these limiting departures occur below the level of maximum rainfall, Colfax being at 2,421 feet, and the maximum rainfall at approximately 5,000 feet.

VII. THE MEAN VARIABILITY OF PRECIPITATION IN CALIFORNIA

1. *Definition of "variability" as here used.*—Following established precedent the terms "departure" and "variability" have heretofore in this paper been used interchangeably, variability signifying what is, strictly speaking, departure; that is, deviation from the mean or average. If, however, average seasonal variability be defined as the average of the differences between successive seasonal totals of precipitation regardless of sign (i. e., regardless of whether the differences represent increases or decreases from one season to the next), and if a comparison of these averages with the average seasonal departures be made, it will be evident that very important practical consequences ensue from the varying relations of departure to variability. As a basis for a brief discussion of this point, the average seaonal variability of rainfall in terms of percentage of the seasonal average rainfalls for 82 stations has been included in Table A. But, as has been pointed out in another connection, the shorter the period the more dubious becomes the value of computing such items as departures, variabilities, etc. Hence in the following section 2 the discussion is based only upon the variabilities at stations having 25 seasons of record.

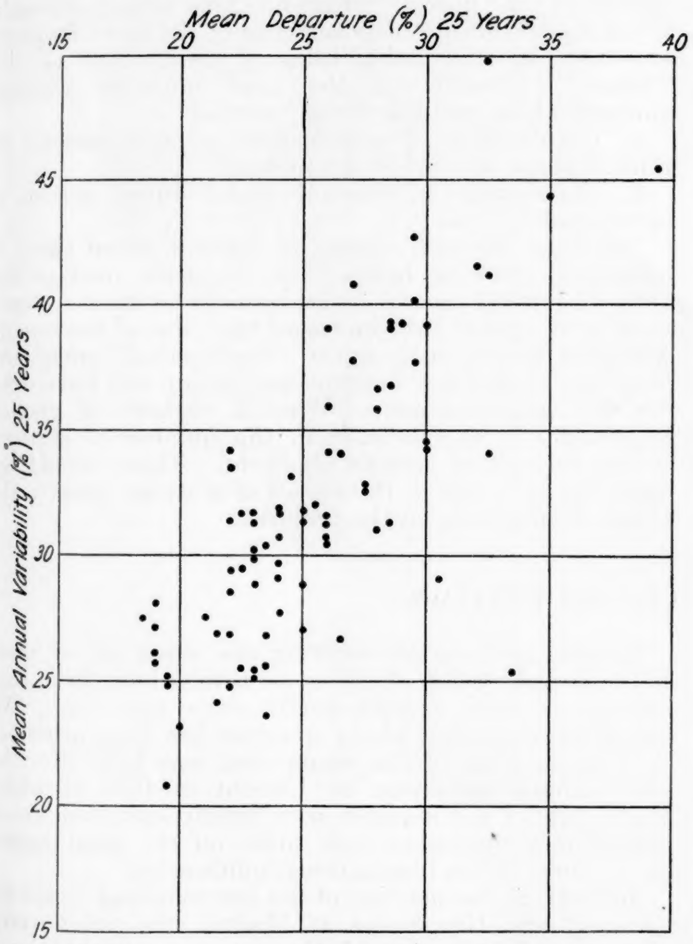

FIG. 11.—Relation of average seasonal percentage departures to average seasonal percentage variability of rainfall on the basis of the uniform 25-season period ending 1919-20

2. *Relations between variability and departure.*—The dependability of rainfall expressed in this manner in a very general way resembles that given in terms of the mean departures from the seasonal averages. But there are some important deviations from this general condition. To show to what extent this is true for California, Figure 11 has been prepared, in which the percentage variabilities are given as ordinates and the percentage departures as abscissae. Vertical and horizontal scales have been made alike in order to preserve the proper dispersion of the two sets of percentages in respect to each other. It is clear that there is a tendency toward a straight line relation between the two sets of values, but that the relation is not close. There are many cases of large departures coincident with small variability and vice versa, and for a given variability departures occur through a rather wide range of values and vice versa. The most significant thing about the relation is that large average departures do not necessarily connote large average variabilities. The occurrences of the departures may take place in groups (a feature which unfortunately can not be seen from the dot chart)—groups in which the departures have the same sign and a high value, this group eventually giving way to one having the opposite sign and equally high value, the change taking place from one season to the next. In such a case the departure is large and the variability relatively small. Rapid oscillations between large excess and large deficiency mean, of course, high values of both departures and variabilities. Equally rapid shifts from small excess to small deficiency give small departures and small variabilities. The complexity of the relations is obvious.

3. *Relation of variability and departure to California water problems.*—For California the ultimate success or failure of water-storage projects depends on how adequate are the preparations made for meeting the infinite variations in the interrelations of these two factors. It should be emphasized that high mean departures entail very different practical consequences according to whether they coincide with high or with low mean variabilities. With high variability rainfall deficiency of one season will in general be soon compensated for by excess in another. Hence reservoir capacity need not be larger than that necessary to care for the demands through two or three seasons. With low variability, however, a high mean departure indicates the tendency for several "dry" or several "wet" years to occur consecutively, in which case the capacity of reservoirs must be sufficient not only to meet current demand but to conserve the excessive receipts of water of the wet periods to meet the requirements during the periods of deficiency. The areal distribution of mean variabilities is set forth on the map in Figure 12 and will be discussed in the following section 4.

4. *The regional distribution of average variabilities in California.*—With 82 stations distributed irregularly over a region like California, a thoroughly satisfactory mapping of variabilities is, like the mapping of departures already discussed, impossible. If, however, we select 10 per cent as the difference between variability values for which isograms shall be drawn, it becomes possible to differentiate in a general way certain large regions. The process involves ignoring, for mapping purposes, the variabilities at some stations which are not in accord with those that are characteristic of the surrounding regions. Thus, in the area labeled "Under 30 per cent," will be found an occasional value over 30 per cent, etc. Interpreting the distribution of the values thus somewhat liberally, it is apparent that the State may be divided into the following regions:

(1) The larger part of the Sierra Nevada, excluding the foothills, appears to have an average seasonal variability of over 30 per cent.

(2) West of this lies a long belt which includes most of the foothills and a considerable strip along the eastern side of the Interior Valley, where a variability under 30 per cent is characteristic. This belt seems to be continued in a fan-shaped area northward and northeastward into the semiarid region of northern California.

(3) West of No. 2 variabilities increase, so that a large part of the eastern Interior Valley and all of its western part, together with a considerable portion of the Coast Range country north of San Francisco Bay, show variabilities well over 30 per cent.

Between region 3 and the coast one may distinguish two fairly definite regions, as follows:

(4) In the northern Coast Ranges, in an area which includes perhaps the western third of them, variabilities are considerably lower than they are east of this region. There is also an apparently well-marked increase in variability from about 20 per cent in the northern part of the area to about 30 per cent around San Francisco Bay. Tracing the figures still southeastward within the Coast Ranges, one finds them rising irregularly to well over 40 per cent in the ranges north of Monterey Bay, decreasing to somewhat under 40 in the region east of the Bay, then rising to over 40 in the southern Coast Ranges.

(5) The southern Coast Ranges average distinctly higher in variability than the northern, the magnitude of it increasing southeastward and eastward into the high values of the southeastern desert.

(6) The southeastern desert is characterized by an extraordinary range of variabilities, including the unaccountably small variability at Lone Pine north of Owens Lake and the maximum value at Bagdad.

(7) Southern California west of the desert is, in the matter of average seasonal variabilities, clearly to be distinguished from the forbidding country at its back. Its variabilities largely stand midway between those of the desert rainfall and those of the fairly dependable rainfall in central and northern California. An exception to this condition is seen in the country north and east of San Diego, where the variabilities appear to be of the same order as those in central and northern California.

CONCLUSION

The foregoing material would seem to suggest that the most important subjects for future studies of this type on California rainfall should be:

1. With the frequency polygons here presented as a point of departure, the determining of the facts regarding (*a*) the relation of the most frequent seasonal totals of rainfall to the "normal" or arithmetical average amount; (*b*) the probabilities of occurrence of the most frequent amount; (*c*) the probabilities of occurrence of the "normal" amount; (*d*) the most probable seasonal amounts above and below the "normal."

2. The duration of periods (one or more seasons) of rainfall above and below the normal.

3. The averages of seasonal rainfall during periods of excess and deficiency.

The basis for such studies as those outlined above is constantly growing better. At this time (end of the 1924–25 rainfall season) five seasons in addition to those used in this paper have increased the value of the record. Many stations formerly in the "short-period" group now have moved into the "long-period" group and have data for 25 seasons or more. What is perhaps of greater importance is the increase in the number of stations having at least 10 seasons of record. These should, by filling many a gap in the *réseau* of stations, greatly aid in any future work on the problem.

NOTES, ABSTRACTS, AND REVIEWS

INTERNATIONAL COMMISSION FOR THE INVESTIGATION OF THE UPPER AIR

[Reprinted from Nature, no. 2898, May 16, 1925, pp. 781–782]

A meeting of the International Commission for the Investigation of the Upper Air was held in London on April 17–22.

At the meeting of the commission in Bergen in July, 1921, the commission adopted the view that the international publication of the results of the investigation of the upper air ought to be resumed, and that an international bureau should be established and supported by contributions from the different States, so that the preparation and compilation of the results should not in future be done at the sole cost of the national service which undertook the work. Unfortunately, it did not prove practicable, in the stringent economic times which followed the meeting of 1921, to obtain the funds which were necessary to carry out the recommendations of the meeting at Bergen. In consequence of this, Prof. V. Bjerknes, who had been president of the commission, resigned his position, as he could not spare the time from his purely scientific work to carry out unaided the large amount of work involved in the preparation and publication of the international upper air results. Sir Napier Shaw, then president of the International Meteorological Committee, took over the presidency of the commission at the request of the members.

Various methods for securing the object of an international publication of upper air results have been considered or tried experimentally since that time. No satisfactory solution of the question has been achieved. A short meeting of the commission was held after the international conference at Utrecht in 1923 at which the results of the inquiries were briefly surveyed, and a preliminary discussion took place on the most appropriate form for an international publication.

In 1924, at the meeting of the International Union for Geodesy and Geophysics at Madrid, the union voted the sum of 500*l*. toward the expenses of publication of a specimen volume of upper air data, and Professor van Everdingen, the director of the Meteorological Institute of Holland, promised a contribution of about 100*l*. for the same purpose.

The meeting of the commission in London was concerned primarily with the consideration of the form which the specimen publication should take. Representatives from the following countries attended: France, Captain Wehrlé; Germany, Professor Hergesell; Great Britain, Sir Napier Shaw, Sir Gilbert Walker, Capt. C. J. P. Cave, Lieut. Col. E. Gold, Mr. L. H. G. Dines, Mr. L. F. Richardson; Holland, Professor van Everdingen, Professor van Bemmelen; Italy, Lieut. Col. Matteuzzi, Professor Gamba; Norway, Doctor Hesselberg; Russia, Doctor Molchanoff; Spain, Colonel Meseguer. The meetings of the commission were divided

FIG. 12.—Isograms of average seasonal variability of precipitation in percentage of the seasonal average rainfall, for stations having 25 seasons of record ending 1919–20

into business meetings and scientific meetings, on the ground that a right solution of the questions which the commission had to consider could only be achieved by a correct appreciation of the scientific principles involved. There were four business meetings and three scientific meetings.

At the first meeting of the commission on Friday, April 17, the president read a letter from Mr. la Cour, director of the Danish Meteorological Service, giving the commission the welcome news that four wireless stations would be in operation in Greenland during the coming summer, at Angmagsalik, Julianehaab, Godthaab, and Godhavn; and that all four stations would be equipped with instruments for observations of pilot balloons. The work of the four stations as regards investigation of upper wind would be coordinated by wireless with the view of obtaining simultaneous ascents to great heights from all stations at the same time.

In a communication from M. Fontséré, Barcelona, an account was given of some observations on oscillations of short period, indicated by the well known oscillations of the motion of pilot balloons, as seen in a pilot balloon theodolite. These oscillations appear to have a period of about three seconds, and do not appear to be due to natural oscillations of the balloon. The commission decided to recommend that a similar investigation should be undertaken in other places, and that the influence of the size and form of the balloon on the character of the oscillations should be explored and that a comparison of the oscillations observed in balloons with those observed in the tension of kite wires should also be made.

After some discussion of the use that should be made of the funds placed at the disposal of the president, the commission decided that they should be applied to the publication of a specimen volume of upper air results for 1923 and 1924, and that in the specimen volume the observations obtained from *ballon-sonde* and similar records from the places selected for international investigation, should be published in the form of tables giving full details, and that the tables should be supplemented by graphical representation on "tephigrams." This is the name given to the representation of the results of the *ballon-sonde* ascents, by plotting corresponding values of temperature t, and entropy ϕ, which is proportional to the logarithm of potential temperature T. This form of representation, which was invented by the president and explained by him at the scientific meeting, is peculiarly appropriate for presenting the results of temperature (and humidity) observations in the upper air. It shows immediately the relation of the temperature gradient observed in the ascent to the adiabatic gradient for dry air and the adiabatic gradient for saturated air. It shows the energy which would be required to raise air vertically in the atmosphere under the conditions of the ascent, or alternatively, the energy that would be set free in a kilogram of air rising in the atmosphere under the conditions of the ascent. It also has the great advantage of presenting these results in a diagram of very moderate dimensions, even when observations at heights of 50,000 feet or more are included.

Considerable discussion took place on a proposal sent by Doctor Marvin for concentrating all the international *ballon-sonde* ascents in any one year into a single month. The proposal to obtain ascents daily for a month in addition to ascents on single days in other months of the year, was advocated by Lieutenant Colonel Gold at the meeting at Bergen in 1921, but it was rejected by the commission on the ground that the funds available for upper-air investigation should be devoted to obtaining results for detailed investigation on the lines adopted by the Norwegian Geophysical Institute. After much discussion of Doctor Marvin's proposal, it was agreed that countries participating in the international investigation of the upper air should be asked to make, so far as possible, daily ascents distributed throughout a month in each year, the month to be selected by the International Commission, these ascents to be additional to those indicated in the scheme of international days prepared by the commission at Bergen for the years up to 1928. The first month selected for this more extended investigation is May, 1926, and the next month is October, 1927. (It was considered that the time was too short to warrant an "international month" in 1925, but it was agreed that any auxiliary *ballon-sonde* results which any country might be able to make, should be made in August.)

In the course of discussion of this resolution, Professor Hergesell emphasized that the international investigation of the upper air has two aspects, the world aspect and the regional aspect. From the world aspect, ascents over a month would be appropriate, and from the regional aspect, ascents concentrated into shorter periods of time, and made more frequently, would lead to better results. Doctor Simpson, following up this line of thought, made the suggestion that the commission itself should deal only with the world aspect and should appoint regional subcommissions to deal with regional aspects. The commission eventually decided that the regional aspect could, in the meantime, be dealt with satisfactorily by the nomination of deputy presidents in the following different regions: Europe, with Russia, Siberia, and North Africa; North America; the East Indies and the Philippines; Australia; South Africa; South America. It was agreed that the six ascents left at the disposal of the president should be concentrated in the international months, and the exact dates in the different regions should be left to the deputy presidents for these regions. Doctor Marvin was designated as deputy president for North America and Mr. J. H. Field for the East Indies.

The question of adopting an international formula for the rate of ascent of balloons, put forward by Doctor Weinberg (Leningrad), led to the appointment of a subcommission to consider this and other questions relating to balloons, and to report to the next meeting of the commission. The members of the subcommission are: Professor Hergesell, president, Doctor Hesselberg, Mr. J. S. Dines, Doctor Molchanoff, Colonol Matteuzzi, Doctor Marvin, and Mr. Fujiwhara.

The importance of airplane observations, and the difficulty of securing satisfactory instruments for them, was emphasized by Captain Wehrlé, and the commission decided to ask for complete particulars of the instruments and methods used in different countries to be communicated, with the view of their publication in collected form by the French meteorological service.

As regards the future, it was decided that the question of a regular international publication could only be settled satisfactorily after the specimen volume had been issued and considered. The question of the publication of results after 1924 was, therefore, remitted to the next meeting of the commission, which it is anticipated will be held at Prague in 1927.

* * * The outstanding impression left by the meeting may be illustrated by a remark to me of one of the foreign delegates:

> What I like about this international work is the way everybody is ready to help things forward; the only consideration being, "Is the thing good?" It is very pleasant.

E. Gold.

THE METEOROLOGICAL CONDITIONS IN THE FREE AIR DURING TWO EXTREME WEATHER TYPES

By W. PEPPLER

[Abstracted from Meteorologische Zeitschrift, March, 1925, p. 114, by Leroy T. Samuels, Weather Bureau, Washington]

The author gives the results of his study of the vertical distribution of temperature, relative humidity, and wind direction over the Lake Constance region as regards its bearing on the weather of southwestern Germany, particularly the Alpine forelands. The data used comprised the kite records obtained at the aerological stations near Lake Constance during the years 1909–1915, these being grouped under two distinct types of weather, viz, with cloudless sky and during the occurrence of precipitation.

A. WITH CLOUDLESS SKY

There were 71 flights available under the first condition, distributed as follows: Summer, 39; spring, 19; autumn, 8; and winter, 5. The mean values found are given in Table 1.

TABLE 1

Altitude (m.)	395 (Surface)	500	1,000	1,500	2,000	2,500	3,000	3,500	4,000
Δt/100 m.	0.03	−0.26	0.50	0.54	0.56	0.56	0.56	0.58	
Δt/100 m. (omitting inversions)	0.51	0.53	0.60	0.62	0.62	0.63	0.61	0.61	
Relative humidity	78	77	54	49	44	40	39	37	35

The author discusses his reasons for expecting a relatively steep average temperature lapse rate under these conditions and follows with explanation for the smaller values actually found.

Table 2 gives the percentage frequency of temperature inversions and isothermal layers which are most regularly present notwithstanding the absence of clouds.

TABLE 2

Altitude (m.)	395–800	810–1,200	1,210–1,600	1,610–2,000	2,010–2,400	2,410–2,800	2,810–3,200	3,210–3,600	3,610–4,000	4,010–4,400
Per cent	$\boxed{98}$	16	20	10	$\boxed{19}$	$\boxed{16}$	5	$\boxed{12}$	6	3

The comparatively high frequencies found between 2,000 m.–2,800 m. and at the 3,200 m. level are discussed and special emphasis placed on the fact that since these stratifications are frequently present even in cloudless weather it is therefore proved that they are not the result of cloud formation. Difficulties seem to arise, however, in accepting the hypothesis that descending air currents extend uniformly over great areas in the inner regions of anticyclones, as is generally supposed, since out of 67 ascents only 5 had no inversions, 19 had 1, 35 had 2, and 8 had 3 inversions.

The decrease of relative humidity up to over 4,000 m. would seem opposed to the supposition that the descent of air from higher altitudes is the cause of its dryness, since if this were true the humidity would necessarily increase with elevation. This latter condition, while found occasionally in individual cases, is not the rule. The fact that on cloudless days the humidity up to great heights amounts to 40–50 per cent is probably of significance in solar radiation measurements which are made in most cases under such weather conditions. The latter are thus related to an atmosphere which has a vapor content well below the mean up to the middle (at least) of the troposphere.

On account of the frequent presence of a transition layer with a calm between 500 m. and 1,000 m. over Lake Constance the usual method of representing the wind shift with height can not be used and the percentage frequency of the cardinal directions is therefore given in tabular form.

The south quadrant of an anticyclone is found to be the most frequent pressure distribution for cloudless weather in this region, since then the winds are opposite to the (Südföhn) foehn, which latter wind is usually accompanied by more or less cloudiness. An interesting relationship was found to exist between cloudless weather and the pressure change during the following 24 hours. In 70 per cent of the cases a fall in pressure occurred and this relation suggests a connection between cloudless weather and the moving anticyclone (cold wave) in which there frequently occurs a complete clearing of the sky.

B. DURING THE OCCURRENCE OF PRECIPITATION

There were 129 flights obtained during the occurrence of precipitation. The mean values found are given in Table 3.

TABLE 3

Altitude (m.)	Surface, 395	500	1,000	1,500	2,000	2,500	3,000	3,500	4,000
Δt/100 m.	0.70	0.62	0.58	0.56	0.56	0.54	0.53	0.51	
Relative humidity	90	90	91	92	92	92	91	87	80

The strikingly different values found for the average temperature lapse rates as compared with those in cloudless weather are ascribed to several causes. In rainy weather the temperature changes below the rain cloud, whose lower limits lie on an average at about 1,500 m., follow the adiabatic rate for dry air while within the cloud the temperature changes according to the adiabatic rate for moist air. At greater heights, above 3,000 m., frequent inversions at the upper limit of the cloud diminish the mean vertical gradients.

The percentage frequency of temperature inversions are given in

TABLE 4

Altitude (m.)	395–800	810–1,200	1,210–1,600	1,610–2,000	2,010–2,400	2,410–2,800	2,810–3,200	3,210–3,600	3,610–4,000	4,010–4,400
Per cent	14	4	5	2	5	1	3	12	4	13

From this it is evident that outside of the surface layer inversions are rare below 3,000 m., while above this height they become more frequent, since the upper limit of the less dense rain clouds rarely exceeds this height.

The mean relative humidity values are found to be about 90 per cent from the surface to 3,000 m., above which they show a gradual decrease. The base of the Nb. clouds was found to lie below 1,000 m. in 33 cases, between 1,000 m. and 2,000 m. in 76 cases and above 2,000 m. in 17 cases. The average height of their upper limit was found to be 2,730 m. and their average thickness somewhat more than 1,200 m. In some of the individual cases, however, the upper limit of the cloud was not reached at 4,000 m. By far the most frequent cloud type found showed a gradual decrease in relative humidity without an inversion, i. e., a gradual dissipation of the cloud particles with no well defined boundary.

Only in rare cases was it possible to analyze the temperature distribution as regards the type of precipitation with a view to determining whether the latter was associated with the warm-front, cold-front or an occluded

Low. In relation to these types the following typical surfaces of discontinuity were distinguishable: 1. *Near the surface.*—These appear frequently on the front side of secondary depressions and are related to the shallow cold strata which are separated from the upper warmer current by an abrupt change in temperature. 2. *Inversions with Fr. Nb.*—The mean altitude of these clouds is about 600 m. below the main cloud mass and they are often accompanied by small inversions. With more observational data it would be interesting to investigate the relationship which this condition bears to the Bjerkness theory of surface discontinuities. An inversion was found directly below the main Nb. layer in only 2 cases. 3. *Inversions in the main Nb. layer.*—Slight irregularities are frequent here especially at the beginning and ending of precipitation. 4. *Inversions at the upper limit of the clouds.*—These occur only with relatively thin Nb. from which there is only moderate precipitation, most frequently above 3,000 m. in the A. Cu. level. An adequate explanation of any of the above general classes is hardly possible from the records of only one aerological station.

The author gives in tabular form the percentage frequency of wind direction up to 4,000 m. during the occurrence of precipitation. The predominating direction is west for all heights. The striking characteristic is shown that especially in southern Germany winds with a N-component greatly predominate over winds with a S-component during the occurrence of precipitation. In the Alpine forelands all winds from SE–W have more or less of the foehn character, while those blowing toward the mountains necessarily produce phenomena associated with the forced ascent of air currents. It was found impossible to classify these records according to definite pressure types since in 80 per cent of the cases there was found to be an irregular pressure distribution in which secondary depressions played an important rôle. This latter fact reveals the difficulties in the prediction of precipitation for this region.

Discussion.—The reference by the author to the decrease in the mean relative humidity up to over 4,000 m. and his inference therefrom relative to the supposition that the descent of air from higher altitudes is the cause of its dryness, etc., might lead the reader to suspect some undue influence of local character, since these observations were made near a lake. It therefore would seem of interest here to show the results found for the southeast quadrant of anticyclones in this country as determined from kite observations made at the Drexel Aerological Station near Omaha, Nebr., from 1915 to 1924. These are given in the following table and are based on 50 and 61 flights made during the summer and winter seasons, respectively:

Altitude (m.)		Surface 395	500	1,000	1,500	2,000	2,500	3,000	3,500	4,000	4,500	5,000
Relative humidity.	Summer	78	72	62	57	50	45	45	43	39	40	44
	Winter	89	89	82	67	59	57	56	54	52	51	50

These data represent the ascent only, the average time of which occurred about 7 a. m. and 8 a. m. for summer and winter, respectively. This fact, of course, explains the rapid decrease in the lower levels from the relatively high values found at the surface. It is probable that the same method was used for the European data since this rapid decrease is even more pronounced than for Drexel. This latter fact, however, may be due in part at least to the proximity of the lake. While it is true the European observations were not made under the same conditions so far as the pressure distribution is concerned, yet the American observations were made during conditions favorable for cloudless weather and the downward movement of air. It is evident from this table that under similar circumstances in this country the same condition prevails, viz, a gradual decrease in the mean relative humidity with increase in elevation.—*L. T. S.*

SUNSPOTS AND THE WEATHER AT GALVESTON, TEX.[1]

By I. R. TANNEHILL

[Weather Bureau office, Galveston, Tex., May 25, 1925]

The chief difficulty in coordinating solar and terrestrial conditions lies in the absence of complete series of observations on solar activity. Present observations of that nature cover too short a period to yield permanent results.

The variation in the number of sun spots as related to the weather on the earth has been the subject of numerous studies most of which probably are familiar to the reader. In some of these investigations it is assumed that the effect of changes in solar radiation will be felt throughout the atmosphere, as a general rise or fall in the temperature of the atmosphere as a whole, the effect being greatest in the Tropics. Others have assumed that the changes in the earth's atmosphere will be felt chiefly in the higher levels of the troposphere, that these changes will entail other changes in the surface pressure of the earth, etc. Still others claim, and with reason, that the correlation coefficients will be negative in one region and positive in another.

The writer presents in outline the results of studies of the records of a single station in an effort to associate changes in the spottedness of the sun with terrestrial weather changes.

The wind.—Data of frequency of south and southwest winds in summer months, 1871–1924, smoothed by taking the mean of three consecutive values allocated to the middle year were compiled and plotted in a curve. A curve was also prepared showing the changes from year to year in the frequency of southeast winds for the month of July. This curve is practically the inverse of the curve for south and southwest winds.

There is a rough parallelism between the frequency of south and southwest winds and the curve of sun spots, although the curves for the two elements are at times lacking in synchronism.

Wind velocity data for April and May, the two months best suited to the purpose of the investigation, were prepared and studied. No correction was attempted for the results of a change in the anemometer exposure made in 1901.

An increase in wind velocity with increase in sun spots is noted in four periods between 1880 and 1920, although here again the two curves are not closely congruent. The wind speed for July—a month in which accidental changes in wind speed are at a minimum, by reason of the small number of cyclones which approach within 500 miles of the station—is shown by two curves, the first representing the changes from year to year in the wind speed at the hour of least wind movement, near sunrise, and the second representing the changes for the hour of greatest wind speed, or the converse of the first.

[1] Author's abstract. Original text and illustrations are filed in Weather Bureau Library.

The relation of these two curves to the sun-spot curve is not clear.

The temperature-relation.—A variety of material was collated to illustrate this relation and the conclusion was reached that the reaction of terrestrial temperature to solar changes due to variations in the spottedness of the sun is quite complex and that there are apparently other influences not fully understood.

The rainfall relation is likewise not obvious. I conclude as a final summation of the results of the study:

(1) There are some striking resemblances between the curves of weather elements and that of sun spots, but with numerous irregularities of short period not removed by the smoothing processes.

(2) The change in weather conditions frequently precedes the change in sun spottedness which leads to the inference that they are not related as cause and effect.

(3) There is some evidence that the effect of solar variations differs with the season and the locality.

(4) The problem is quite complex and the meteorological records are of inadequate length for the purpose.

MILD WINTER OF 1924-25 IN BERLIN

Dr. G. Hellmann in the April, 1925, number of the Meteorologische Zeitschrift briefly summarizes the winter of 1924-25 in Berlin. That winter, counting from December 1 to February 28, as usual, proved to have been the third mildest in the last 160 years, the winter of 1795-96 only being milder and the winter of 1868-69 being almost exactly as mild; the latter, however, was broken by a ten-day cold period in January. An unusually warm February—about 4.3° C. above normal—was common to both winters. * * * The temperature in 1924-25 ranged from −7.5° to 15.3° C. (18.5°–59.5° F.).

The winter belongs to the dry-mild type and this type occurs less frequently than the wet-mild type.

Doctor Hellmann notes that the usual spell of inclement weather which usually follows a very mild winter was not lacking.

Here in the United States, although February was exceptionally warm, both March and April were devoid of unseasonable weather.—*A. J. H.*

THE NATIONAL ELIMINATION BALLOON RACE FROM ST. JOSEPH, MO., MAY 1, 1925

[Extracts and notes based on a report by W. S. Belden, United States Weather Bureau, St. Joseph, Mo.]

The National Elimination Balloon Race in 1925 started from the aviation field in St. Joseph, Mo., late in the afternoon of May 1. Five balloons were entered in the race.

At St. Joseph, May 1 was clear with temperature considerably below normal, ranging from 39 to 62 degrees. Northwest wind prevailed from 3 p. m., April 28 to 8 p. m., May 1. The wind attained gale force on the forenoon of the 29th and was light to fresh on the 30th and 1st, the maximum velocity for a period of five minutes on each of the last two dates being 24 miles per hour from the northwest. The wind on the afternoon of May was rather gusty, the extreme velocity covering a period of two to three minutes of each hour from 1 to 6 p. m. being at the rate of 23 to 25 miles per hour.

Each pilot was furnished detailed meteorological reports and charts based on aerological observations made at 12 well distributed stations on the afternoon of April 30 and at 7 a. m. and 11 a. m., May 1. Numerous pilot balloon runs were made May 1 at the local aviation field by the United States Army meteorological service. Other information furnished by the Weather Bureau included daily weather maps, daily weather bulletins, forecasts for Missouri, Kansas, Nebraska and Iowa, a special weather summary and indications issued by the district forecaster at Chicago, based on special noon observations May 1, and schedules of radio broadcasts for the benefit of the contestants, three of which carried radio receiving sets. Forecasts and summaries of upper air conditions were broadcast for the benefit of the pilots at intervals during the time the balloons were in the air. These radio bulletins were prepared by the Weather Bureau at Washington and Chicago and sent by telegraph to a number of broadcasting stations that were most favorably located with respect to the probable path of the balloons.

On starting, the balloons were carried to the south-southeast. Those rising to higher levels within a few hours after starting moved more in a southeasterly direction and at a greater speed than those keeping nearer the ground. The courses of all the balloons were the results of winds flowing from a ridge of high pressure which extended from Canada to the Gulf of Mexico The winning balloon, piloted by Mr. W. T. Van Orman, aided by Mr. C. K. Wollam, landed near the town of Reform, Ala., exactly 36 hours out, and 585 miles from St. Joseph.

OROGRAPHIC WIND AS AN AID TO GLIDING FLIGHT IN AIRPLANES

The remarkable development in man's ability to take advantage of the upthrust of air over ridges for prolonged gliding flight, is shown by the report (Aviation, April 20, 1925, p. 439) of the achievements of Lieutenant Thoret and a pupil of his, both of the French Air Service. In 1923 Lieutenant Thoret remained in the air for 7 hours, with his engine completely cut off. Sergeant Wernert recently glided for 9 hours and 17 minutes in the same manner. On the day when he established this record, a high wind was blowing across the ridge which is the scene of the soaring tests, developing, as nearly as can be inferred from the description, a standing wave about 2 km. wide and 4 to 5 km. long over the ridge. Along the crest of the ridge Wernert glided at some 50 to 300 yards above and in front of it, "at all times maintaining a great reserve of flying speed. He tacked up and down in front of the hill all day" and finally toward sunset, the air becoming disturbed in a manner ascribed to cooling of the air in the shadow of the hill, soaring flight became increasingly difficult. "A perfect landing was made by moonlight."—*B. M. V.*

METEOROLOGICAL SUMMARY FOR APRIL AND MAY, 1925, FOR ARGENTINA, CHILE, PARAGUAY, AND BOLIVIA

[Reported by Señor Julio Bustos Navarrete, El Salto Observatory, Santiago, Chile]

April.—During April the weather was rather rainy in all of the southern part of the continent, while in northern Argentina and in Uruguay it was generally of the type occurring with the domination of high atmospheric pressure. On the Bolivian plateau there were days with severe cold, and frosts were frequent.

On the 2d and 3d scattered rains fell in Argentina.

The first important cyclonic depression appeared on the 5th; it controlled conditions in central and southern Chile,

and caused moderately heavy rains from Valparaiso to Chiloe. From the 6th to the 14th high pressure prevailed over the southern Chilean Provinces and it was accompanied by fair weather over the entire central belt.

In Argentina and Paraguay scattered rains occurred again on the 11th and 12th.

On the 15th an important atmospheric depression appeared from the west and began to influence conditions in southern Chile; on the 16th the center of this area with a minimum pressure of 29.65 inches (753 mm.) was situated off Isla Mocha; on the 17th it was found more to the north, but the convergent winds, which were abnormal by excess [that is, of velocity too great in proportion to the pressure gradient],[1] caused a filling up according to the law of Guilbert.

Between the 15th and the 20th there were several depressions moving from west to east and causing continued unsettled weather in the extreme southern part of the continent.

Some snow fell in Magellanes on the 22d; this was followed by a heavier fall on the 25th accompanied by a cold wave.

Another period of atmospheric disturbance in the southern region began on the 26th. On the 28th a depression extended from the Juan Fernandez Islands to Isla Mocha and caused continued rains from Concepcion southward. On the 30th an extensive depression dominated conditions over the entire southern part of the continent. At Cabo Raper the pressure fell to about 28.94 inches (735 mm.) and at Temuco and on the island of Huafo the north wind attained a velocity of 63 miles per hour. In all southern Chile the rainfall was very heavy.

May.—In all of the southern region of the continent the first half of the month was rainy, but the remainder was relatively dry with periods of severe cold. The lowest temperatures were observed in the region of Chos Malai, Las Lajas, and Bariloche (Chubut) in Argentina and Lonquimay in Chile, stations which lie within the "cold pole" of the continent of South America.[2] In this region minimum temperatures frequently fluctuated between 23° and 14° and even ranged down to 9°.

During the passage of a depression across the southern region from the 1st to the 3d rain fell over southern and central Chile northward to the province of Aconcagua (north of Santiago). Scattered precipitation occurred in Rio Negro on the 1st and 1 inch of rain fell at Buenos Aires on the 3d.

The rise in pressure on the 4th was accompanied by a general fall in temperature in southern Chile.

From the 5th to the 7th a depression was approaching off the coast of central Chile; on the 8th it began to affect conditions on the continent and heavy rains fell between Coquimbo and Chiloe. At the same time another depression between Buenos Aires and Bahia Blanca was accompanied by heavy rains and electrical storms.

On the 9th there was a second rise in pressure over southern Chile and by the 10th this resulted in an important anticyclonic area with maximum pressure above 30.32 inches (770 mm.) in Chiloe. This center with certain changes persisted until the 19th and the period of its duration was characterized by severe cold waves in the southern part of the continent.

The depression which crossed the southern region on the 20th was accompanied by rains between Malleco and Magellanes on the 21st.

On the 22d pressure rose again in southern Chile, forming an extensive center with maximum pressure 30.39 inches (772 mm.) between Isla Huafo and Cipolleti, Argentina, and bringing another severe cold wave.

During the passage of a depression on the 23d the pressure fell to 28.82 inches (732 mm.) at Punta Arenas, and on the following day there was heavy snowfall in the region of Magellanes.

The southern anticyclonic center was reestablished on the 25th and the pressure was above 30.32 inches (770 mm.) at Valdivia; this center with some changes persisted until the close of the month and brought another period of severe cold.

[1] See Fassig, O. L.: Guilbert's Rules for Weather Prediction, Mo. Weather Rev., May, 1907, 35: 210, and on pp. 211–212, the translation by Fassig of Guilbert's "Principles of Forecasting the Weather."

[2] These stations lie between latitudes 37° and 41° S., and the elevations above sea-level range from 2,340 to 3,180 feet.

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SOLAR OBSERVATIONS

SOLAR AND SKY RADIATION MEASUREMENTS DURING MAY, 1925

By HERBERT H. KIMBALL, Solar Radiation Investigations

For a description of instruments and exposures and an account of the method of obtaining and reducing the measurements the reader is referred to the REVIEW for January, 1924, **52**:42 and January, 1925, **53**:29.

From Table 1 it is seen that solar radiation intensities averaged below normal values for May at all three stations.

Table 2 shows that the total solar and sky radiation received on a horizontal surface averaged above normal at the three stations for which weekly normals have been determined.

At Washington skylight polarization measurements made on 6 days give a mean of 48 per cent, with a maximum of 56 per cent on the 2d. At Madison, measurements made on 9 days give a mean of 49 per cent with a maximum of 60 per cent on the 23d. These are slightly below normal values for May at both stations.

TABLE 1.—*Solar radiation intensities during May, 1925*

Washington, D. C.

[Gram-calories per minute per square centimeter of normal surface]

Date		Sun's zenith distance									
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass									Local mean solar time
		A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.
May 2	5.56			0.79	1.01	1.28					3.81
4	7.57		0.62	0.76	0.98						5.56
8	5.36			0.76	0.96						3.45
15	8.81			0.34	0.56	0.87					9.83
16	10.97		0.41	0.48							12.68
19	8.48	0.59	0.69	0.81	1.06	1.29					7.87
20	9.14		0.48	0.62	0.81	1.10	0.88	0.72	0.52		7.04
21	7.57				0.86						6.27
23	13.51			0.74	0.98	1.26					14.60
27	5.79		0.77	0.94	1.11	1.32					5.56
28	6.27					1.21					7.04
Means		**(0.59)**	**0.59**	**0.69**	**0.93**	**1.19**	**(0.88)**	**(0.72)**	**(0.52)**		
Departures		**−0.04**	**−0.12**	**−0.12**	**−0.05**	**−0.09**	**−0.10**	**−0.05**	**−0.17**		

TABLE 1.—*Solar radiation intensities during May, 1925*—Contd.

Madison, Wis.

Date		Sun's zenith distance									
	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
	75th mer. time	Air mass									Local mean solar time
		A. M.					P. M.				
	e.	5.0	4.0	3.0	2.0	*1.0	2.0	3.0	4.0	5.0	e.
	mm.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.	mm.
May 1	3.99					1.42					5.36
2	3.63					1.46					4.75
7	3.30				1.22	1.40					4.37
8	6.02				1.02						5.79
11	3.63				0.98	1.42	1.02				4.37
14	3.99					1.40	0.97				4.57
17	3.81				1.19						4.95
18	5.36					1.38					6.27
19	6.50			0.72	0.92	1.31	1.06				7.29
20	9.14				0.94						12.24
21	9.14					1.02					9.83
23	9.83				1.17	1.35					8.48
25	3.99				1.15	1.43					4.37
26	6.02				0.93	1.44					5.56
28	9.14				1.15						8.18
Means				**(0.72)**	**1.07**	**1.37**	**1.02**				
Departures				**−0.23**	**−0.04**	**+0.01**	**−0.02**				

Lincoln, Nebr.

Date	8 a.m.	78.7°	75.7°	70.7°	60.0°	0.0°	60.0°	70.7°	75.7°	78.7°	Noon
May 1	3.99	0.73	0.81	0.99	1.22	1.51					3.45
4	5.36		0.75	0.91	1.05						3.99
6	3.99	0.43	0.51	0.67	0.90	1.29					3.45
11	4.75			0.86	1.12	1.38					3.15
25	4.37						1.15	0.90	0.75		4.37
Means		**(0.58)**	**0.69**	**0.86**	**1.07**	**1.39**	**(1.15)**	**(0.90)**	**(0.75)**		
Departures		**−0.13**	**−0.12**	**−0.10**	**−0.07**	**±0.00**	**+0.04**	**−0.03**	**−0.04**		

* Extrapolated.

TABLE 2.—*Solar and sky radiation received on a horizontal surface*

[Gram-calories per square centimeter of horizontal surface]

Week beginning—	Average daily radiation					Average daily departure from normal		
	Washington	Madison	Lincoln	Chicago	New York	Washington	Madison	Lincoln
	cal.	cal.	cal.	cal.	cal.	cal.	cal.	cal.
Apr. 30	439	434	556	340	342	−10	−12	+84
May 7	377	539	467	490	302	−83	+78	−24
14	524	564	537	488	418	+56	+89	+27
21	530	551	658	506	413	+52	+74	+149
28	611	544	471	484	388	+123	+61	−52
Excess or deficiency since first of year on June 3, 1925						−35	+434	+7

WEATHER OF NORTH AMERICA AND ADJACENT OCEANS

NORTH ATLANTIC OCEAN

By F. A. YOUNG

The following table shows the average sea-level pressure for the month at a number of land stations on the coast and islands of the North Atlantic. The readings are for 8 a. m. 75th meridian time, and the departures are only approximate, as the normals were taken from the Pilot Chart and are based on Greenwich mean noon observations, which correspond to those taken at 7. a. m. 75th meridian time.

Station	Average pressure	Departure
	Inches	*Inches*
St. Johns, Newfoundland	29.90	−0.10
Nantucket	29.95	−0.06
Hatteras	29.99	−0.02
Key West	29.95	−0.03
New Orleans	29.99	+0.03
Swan Island	29.83	−0.04
Turks Island	30.00	0.00
Bermuda	30.10	+0.02
Horta, Azores	30.19	+0.08
Lerwick, Shetland Islands	29.77	−0.03
Valencia, Ireland	29.71	−0.24
London	29.81	−0.11

It will be seen from above table that the pressure at Lerwick was nearly normal, and at Horta slightly below, indicating that both the Icelandic low and North Atlantic high were fairly well developed. At Lerwick the barometric readings ranged from 29.08 inches on the 28th to 30.23 inches on the 14th, and at Horta from 29.66 inches on the 1st to 30.54 inches on the 10th.

Judging from reports received to date, the number of days with winds of gale force was greater than usual over the eastern section of the northern steamer lanes, while conditions were not far from normal over the middle and western sections.

Fog was unusually prevalent during the month over the region between the 60th meridian and New England coast, where it was reported on from 14 to 16 days. Fog also occurred on from 6 to 8 days over the eastern section of the steamer lanes, and on 2 days in the vicinity of the Azores.

On the 1st and 2d there was a well developed depression of limited extent central a short distance northwest of the Azores, and vessels in the northerly quadrants experienced moderate to strong easterly gales. On the 2d high pressure prevailed on the European coast, the barometer at Scilly Islands reading 30.19 inches. By the 3d it had fallen considerably and on that date there was an area of low pressure central about 300 miles west of the west coast of Ireland, that according to reports was not accompanied by winds of higher force than 5.

On the 3d a vessel near 38° N., 42° W., encountered a northerly wind, force 9, barometer 29.98 inches, but did not render a storm log, and other ships not far distant reported only moderate conditions.

On the 4th and 5th the European low had developed into a severe disturbance, and on both of these dates strong westerly to northwesterly gales, accompanied by hail prevailed over the region between the 45th and 55th parallels and the 10th and 25th meridians. By the 6th this low was over the Irish Sea and the storm area had contracted, although northerly gales were still reported from the westerly quadrants.

From the 7th to 9th the pressure was considerably above normal at the Azores and below on the coast of northern Europe. The unusually steep gradient, however, did not result in any abnormal conditions, as moderate winds were the rule over practically the entire ocean during this period.

On the 6th and 7th winds of gale force were encountered in the vicinity of the Canal Zone, as shown by storm report from the American S. S. *F. H. Hillman*, in the table.

From the 10th to 17th low pressure prevailed over the eastern section of the steamer lanes, where winds of gale force were encountered during this period, the storm area reaching its greatest extent on the 16th, when northerly gales prevailed over the region between the 50th and 60th parallels and 20th and 35th meridians.

From the 11th to 13th northerly to northeasterly gales accompanied by comparatively high barometric readings were reported by vessels between Madeira and Gibraltar.

From the 17th to 19th low pressure prevailed in the vicinity of Newfoundland and reports of moderate gales were received from vessels north of the 35th parallel west of the 60th meridian.

On the 20th there was apparently a slight depression about half way between the Bermudas and Newfoundland that moved slowly northward and on the 22d and 23d was over the latter island. On the 21st the center of this low, which was of very limited extent, was about 200 miles south of Halifax, where southwesterly winds of almost hurricane force were reported by the French S. S. *Honduras*, as shown in the table. Ships not over 100 to 200 miles from the *Honduras* on the 21st, recorded winds of force 1 to 4, and the land station at Sable Island, wind southeast, force 1, barometer 29.92 inches, which shows the highly concentrated nature of this disturbance.

On the 22d and 23d vessels in the vicinity of the Gulf of St. Lawrence encountered moderate northeasterly to southwesterly gales.

On the 22d there was a moderate low central near 50° N., 15° W., that drifted slowly eastward and on the 25th was over the British Isles, with moderate gales between the 20th meridian and European coast.

On the 24th there was apparently a slight depression in the Gulf of Mexico that moved northeastward along the American coast, and on the 25th was central near Hatteras. This low was not accompanied by heavy weather over an extensive area, although the American S. S. *Gulflight* experienced a southerly gale in the vicinity of Key West, as shown in table.

On the 26th there was a well defined disturbance central near 50° N., 25° W., that moved slowly eastward and was over the North Sea by the end of the month.

Charts VIII to XI give the conditions from the 27th to 30th, inclusive, and show how intermittent this disturbance was in character as on the 27th, 29th, and 30th the eastern section of the steamer lanes was swept by strong westerly gales that continued well into June, while on the 28th few storm reports were received from vessels in these waters.

On the 27th northeasterly gales were encountered off the east coast of Florida, as shown on Chart VIII.

GALES IN THE SOUTH ATLANTIC AND SOUTH PACIFIC OCEANS

Weather Reports received for May, 1925, contain mention of several gales that occurred in connection with cyclonic disturbances in the South Atlantic and South Pacific Oceans during the month. These gales will be found listed in the accompanying table.—(*A. J. McC.*).

Ocean gales and storms, May, 1925

Vessel	Voyage: From—	Voyage: To—	Position at time of lowest barometer: Latitude	Position at time of lowest barometer: Longitude	Gale began—	Time of lowest barometer	Gale ended—	Lowest barometer	Direction of wind when gale began	Direction and force of wind at time of lowest barometer	Direction of wind when gale ended	Highest force of wind and direction	Shifts of wind near time of lowest barometer
North Atlantic Ocean			° ′	° ′				Inches					
Sac City, Am. S. S.	Norfolk	Rotterdam	45 45 N.	32 38 W.	Apr. 29	4 p., 1st	1st	29.53	E.	E., 5	E.	E., 8	E.-ENE.
Aquitania, Br. S. S.	New York	Southampton	42 45 N.	39 57 W.	May 1st	4 a., 2d	2d	29.70	N.	NNE	NE	NNE., 8	NNE.-NE.
Hoosac, Br. S. S.	Liverpool	Boston	51 14 N.	14 30 W.	4th	4th	5th	29.61	W.	N., 8	NW	——, 10	W.-NW.-N.
Bay State, Br. S. S.	Norfolk	London	49 24N.	14 08 W.	5th	Noon, 6th	6th	29.63	NNW	NNW., 9	NNW	——, 9	Steady.
F. H. Hillman, Am. S. S.	Canal Zone	do	11 10 N.	77 28 W.	6th	8 a., 6th	8th	29.92	NE	NE., 6	E	NE., 8	NE.-E.
California, Dan. M. S	New York	Copenhagen	57 00 N.	18 30 W.	10th	9 a., 11th	14th	29.66	WNW	NW., 7	WSW	NW., 9	Steady.
Londonier, Belg. S. S.	Bahia Blanca	Hamburg	32 34 N.	14 00 W.	11th	Mid., 12th	13th	29.88	NE		NE	NE., 8	
Argosy, Am. S. S.	Copenhagen	New York	56 20 N.	22 30 W.	14th	4 a., 15th	17th	29.40	SW	WSW., 4	NNW	——, 9	WSW.-NW.
Colonian, Br. S. S.	Avonmouth	Montreal	52 06 N.	21 42 W.	16th	11 a., 16th	17th	29.54	WSW	NW., 8	NNW	NW., 9	WSW.-NW.-WNW.
Cadillac, Br. S. S.	Baton Rouge	Avonmouth	37 53 N.	66 42 W.	18th	4 a., 18th	18th	29.88	SW	SW., 7	NW	SW., 8	WSW.-SW.-NW.
Honduras, Fr. S. S.	Scilly Is.	New York	41 11 N.	58 03 W.	21st	6 a., 21st	21st	29.30	SW	SW	NW	SW., 11	
Masconomo, Ger. S. S.	Hamburg	Port Arthur	47 24 N.	18 50 W.	22d	4 a., 22d	22d	29.50	N.	N., 8	NW	N., 8	N.-NW.
Laguna, Br. S. S.	Tuxpam	Montreal	47 15 N.	60 10 W.	23d	23d	23d	29.19	WNW	WSW	WNW	WNW., 8	WSW.-WNW.
West Totant, Am. S. S.	New Orleans	London	48 00 N.	16 20 W.	23d	4 a., 24th	24th	29.38	NW	NW., 6	WNW	——, 8	
Gulflight, Am. S. S.	Bayonne, N. J.	Port Arthur	24 30 N.	81 25 W.	24th	8a., 24th	24th	29.68	S.	S., 7	S.	S., 8	Steady.
West Quichee, Am. S. S.	Liverpool	Boston	51 00 N.	23 42 W.	26th	10 p., 26th	30th	29.36	WSW	W., 9	W.	W., 10	WSW.-W.-WNW.
Cadillac, Br. S. S.	Baton Rouge	Avonmouth	50 50 N.	11 54 W.	26th	8 p., 27th	28th	29.14	WSW	WSW., 9	NW	WSW., 9	W.-WNW.-WSW.
Oscar II, Dan. S. S.	Oslo	New York	49 07 N.	36 28 W.	28th	8 p., 28th	29th	29.44	SW	WSW., 8	WNW	WNW., 9	WSW.-WNW.
Verbania, Br. S. S.	London	Montreal	50 55 N.	26 47 W.	29th	6 a., 29th	30th	29.22	WSW	WSW., 9	WNW	W., 9	WSW.-W.
Kenbane Head, Br. S. S.	Montreal	Belfast	54 38 N.	22 45 W.	29th	6 p., 29th	30th	29.00	W.	W., 8	W.	W., 9	Steady.
Bay State, Br. S. S.	Belfast	New York	55 20 N.	8 20 W.	30th	Mid., 30th	June 5th	28.99	W.	W.	WSW	——, 12[1]	Steady.
South Atlantic Ocean													
Lorraine Cross, Am. S. S.	Bahia Blanca	Buenos Aires	39 35 S.	59 30 W.	7th	4 p., 8th	8th	29.13	ENE	NE., 8	NNE	NNE., 10	E.-NE.
Spar, Dutch S. S.	Hamburg	River Plate	33 15 S.	51 48 W.	11th	6 a., 11th	11th	29.94	WNW	WNW., 8	W.	WNW., 8	WNW.-W.
West Neris, Am. S. S.	Port Arthur	Buenos Aires	29 30 S.	49 04 W	13th	4 p., 13th	15th	29.45	NW	NW., 6	W. by S.	WNW., 8	NE.-NW.
South Pacific Ocean													
Aorangi, Br. M. S.	Sydney	Auckland	34 24 S.	167 25 E.	8th	11 p., 9th	11th	29.99	E. by N.	E., 8	ENE	E. by N., 8	
Canadian Britisher, Br. S. S.	do	Panama	34 00 S.	146 30 W.	9th	8 p., 9th	10th	29.06	NW	NNW	NW	——, 9	NNW.-NW.
West Jappa, Am. S. S.	San Francisco	Buenos Aires	53 20 S.	73 10 W.	9th	7 p., 9th	10th	29.73	NW	NW., 7	SW	NW., 8	NW.-SW.
Eastern Moon, Am. S. S.	Sydney	Panama	27 11 S.	136 25 W.	17th	3 p., 18th	18th	29.86	SE	SSE., 9	SE	SSE., 9	SSE.-SE.
North Pacific Ocean													
Africa Maru, Jap. S. S.	Yokohama	Victoria	50 13 N.	140 00 W.	3d	8 a., 3d	4th	29.69	SE	SE	ESE	SE., 8	
Pres. Madison, Am. S. S.	Seattle	Yokohama	52 14 N.	145 05 W.	5th	10 p., 5th	6th	29.39	S.	S., 5	WSW	S., 8	
Do	do	do	48 55 N.	174 20 E.	10th	11 a., 10th	13th	29.02	NW	NW., 7	NW	NW., 8	NW.-WNW.-NW.
Storviken, Nor. S. S.	Hakodate	Puget Sound	47 33 N.	174 33 E.	7th	Noon, 7th	9th	28.96	ENE	SE., 5	W.	SW., 8	ESE.-S.-SSW.
West Ison, Am. S. S.	Yokohama	Seattle	36 48 N.	143 38 E.	8th	4 p., 8th	10th	29.42	N.	N.	NE	NE., 8	N.-NNE.-NE.
Do	do	do	41 24 N.	156 31 E.	14th	8 p.	14th	29.35	E.	E.	E.	E., 8	E.-SE.
Akibasan Maru, Jap. S. S.	do	San Francisco	35 00 N.	140 30 E.	8th	4 p., 8th	10th	29.36	SW	SW., 7	SE	NE., 9	
Do	do	do	43 12 N.	159 30 E.	12th	3 a., 13th	13th	29.13	ESE	E., 9	SSW	ENE., 10	
Hoyeisan Maru, Jap. S. S.	do	do	48 03 N.	169 53 E.	8th	4 p., 10th	11th	28.99	SW	SW., 6	SW	W., 8	
West Carmona, Am. S. S.	San Francisco	Yokohama	43 22 N.	161 06 E.	9th	9 p., 9th	10th	28.83	S.	NW., 10	NW	NW., 10	S.-NW.
Tacoma, Br. S. S.	Nagasaki	San Francisco	43 48 N.	165 28 E.	9th	2 p., 9th	12th	29.12	ESE	ESE., 10	NW	SW., 11	ESE.-SW.-NW.
Tahchee, Br. S. S.	Cavite, P. I.	do	41 00 N.	155 E.	10th	1 a., 14th	14th	29.31	ENE	NW., 7	NW	NW., 9	
Arizona Maru, Jap. S. S.	Yokohama	Victoria	45 24 N	164 10 E.	21st	4 p., 21st	22d	29.32	WNW	WNW., 6	NW	NW., 8	Steady.
Iyo Maru, Jap. S. S.	Victoria	Yokohama	49 47 N.	171 41 E.	21st	8 p., 21st	22d	29.08	NNE	NE	NW	NW., 8	NNE.-NE.
Pres. Jefferson, Am. S. S.	Yokohama	Seattle	44 10 N.	159 20 E.	21st	9 a., 21st	22d	29.73	W.	NW., 7	N.	NW., 8	W.-NW.-N.
Tuscaloosa City, Am. S. S.	San Pedro	Honolulu	33 18 N.	120 27 W.	30th	6 a	30th	29.90	W.	W., 8	WNW	W., 8	W.-NW.

[1] Highest force of wind on June 4 and 5.

NORTH PACIFIC OCEAN

By WILLIS EDWIN HURD

For the third successive month the eastern North Pacific anticyclone well maintained its average position and strength. In May its crest lay generally between the 30th and 40th parallels, but fluctuated east and west between the 130th and 165th meridians of west longitude. No depressions entered its area from the south, but lows from the Aleutian center broke into its eastern slope and lay off the California coast, central in 35° to 40° N., 135° to 140° W., on the 11th to 13th and 15th to 19th, causing unsettled weather and variable winds, but without gales, although pressures descended as low as 29.40 inches on two or three days.

The Aleutian low was somewhat more energetic than in April. This condition was not apparent while it occupied the Gulf of Alaska during the first six or seven days of the month, although moderate to fresh gales occurred near the 50th parallel, 140th to 145th meridians, on the 4th to 7th, accompanied by snow and hail squalls. The two periods of greatest intensity were those of the 8th to 13th and the 21st to 24th.

The disturbance of the earlier period was apparently a progressive cyclone of the Aleutian type. It seems to have originated not far from 40° to 45° N., 160° E., on the 8th. Thence it moved east-northeast and arrived over the central Aleutians on the 11th, after which it lost greatly in force and drifted into the Gulf of Alaska, finally moving southeastward and dissipating on the 19th near 32 N., 135° W. The cyclone acquired full storm force on the 10th, on which date the British S. S. *Tacoma* encountered a southwest gale, force 11, in 43° 48′ N., 165° 28′ E. This was the strongest wind reported for the month. The lowest pressure observed in connection with the storm was 28.83 inches, read on board the American S. S. *West Carmona*, in 43° 22′ N., 161° 06′ E., on the 9th. It is also to be noted that fresh to strong gales occurred on the 8th to 11th along the northern steamer routes between 160° E. and the Japanese coast.

The second disturbed period, that of the 21st to 24th, was characterized by gales of much less intensity, no wind forces exceeding 8 being reported. The pressure, however, gave the low estreadings of the month, with the minimum, 28.56 inches, occurring at Dutch Harbor on the 22d.

The following table of pressure data is made from the records of the various island stations, as well as from a few American coast stations. Averages are for both 8 a. m. and 8 p. m. observations, 75th meridian time, except as noted:

Station	Average pressure	Departure from normal	Highest	Date	Lowest	Date
Dutch Harbor	[2] 29.58	−0.34	30.10	3d	28.56	22d.
St. Paul [1]	[2] 29.66	−0.20	30.26	3d	28.82	22d.
Kodiak [1]	[2] 29.72	−0.15	30.24	15th	29.28	5th.
Midway Island [1]	30.09	0.00	30.18	21st [3]	29.96	4th–5th.
Honolulu	30.07	+0.01	30.17	27th	29.89	3d.
Juneau	29.93	−0.06	30.33	3d	29.45	27th.
Tatoosh Island	30.00	−0.04	30.33	2d	29.75	10th.
San Francisco	29.95	−0.03	30.13	21st	29.73	25th.
San Diego	29.94	+0.01	30.06	27th	29.73	25th.

[1] P. m. observations only.
[2] For 30 days only.
[3] And other dates.

No tropical storms have been reported as occurring during May off the lower American coast or in the Far East. Low pressure, incident to the season, prevailed off the China coast.

In the Hawaiian area the weather was largely dominated by the great anticyclone to the northward. At Honolulu, the prevailing wind was east, with a maximum velocity at the rate of 32 miles an hour from the same direction, on the 7th. This was the second highest maximum velocity ever recorded in May. The average velocity was 10 miles an hour. The rainfall was less than the normal, though the skies were well clouded, as they were during May over a considerable part of the North Pacific.

A considerable amount of fog was encountered by vessels along the northern routes in west longitudes, and between the 30th and 50th parallels in east longitudes. In the latter region there was a considerable increase in the occurrence of fog over that of April. A report from the American S. S. *West Cajoot*, Hongkong to San Francisco says: "From May 1 to May 7, inclusive, in 38° N., 153° E. to 167° W., experienced approximately 75 per cent fog, mostly low and very wet." Little fog was noted on the Asiatic or American coasts, except that it was observed on six days outside of San Francisco Harbor.

DETAILS OF THE WEATHER IN THE UNITED STATES

GENERAL CONDITIONS

A shortage of precipitation was rather general in central and eastern districts and curiously enough there were very generous rains in California, sufficiently heavy to injure the crops locally in that State.

In eastern districts an outburst of summer temperatures was experienced on the 23d–24th. This outburst was suddenly brought to a close by a wave of cool weather that swept southward on the 25th–26th. On the whole the month was warm in the West and cool in the East, the Rocky Mountains being an approximate dividing line.—*A. J. H.*

CYCLONES AND ANTICYCLONES

By W. P. DAY

The number of low-pressure areas charted during the month was less than the normal and these lows were generally of little intensity. In contrast, the high-pressure areas, though about normal in number, were important in their effects. They were also unusual in being in nearly every case of the type that pushes southward from the Canadian interior, masses of cool air of immediate polar origin. The migratory Pacific type of high, which is usually common at this season, was hardly noted. The effect of this succession of Canadian-interior highs was a series of marked depressions in temperature throughout the month, the greatest departure from the normal occurring in connection with the high of May 24–27.

FREE-AIR SUMMARY

By V. E. JAKL

Changes in free-air temperatures from day to day during the month at the various aerological stations were similar to those on the ground, except that the magnitude of these changes was as a rule less aloft than near the surface. Notwithstanding these changes, some of which

were pronounced, particularly in the lower levels, temperature departures were fairly uniform with altitude, Broken Arrow, Drexel, Ellendale, and Groesbeck showing about normal average temperatures at all altitudes observed, while at Due West and Royal Center it was uniformly slightly cooler than normal at the various levels. (See Table 1.)

Average humidities at all stations were below normal, but not sufficiently so to show any significant relation to the prevalent subnormal precipitation during the month. From this it may be inferred that the deficiency of precipitation was due not so much to lack of moisture content of the air as the lack of suitable conditions to cause ascending currents.

Resultant winds, considering both kite (Table 2) and pilot-balloon observations were approximately normal, except that the winds in the higher altitudes (above about 2,000 meters) showed a rather distinct northwesterly trend, as distinguished from the general westerly direction normal for the month at those levels. In the lower levels the winds were somewhat variable, but showed on the whole a trend mostly from the south over the Plains States and from about west over sections to the east.

In previous monthly free-air summaries mention has been made of numerous instances of weak surface pressure gradients accompanied by comparative calm near the ground and winds of strong to gale force at high altitudes. Such cases can usually be attributed to increase in pressure gradient with altitude due to latitudinal or longitudinal differences in temperature. Cases are frequently observed, however, where the wind velocity at a comparatively moderate altitude is greatly in excess of that indicated by the surface pressure gradient. In such cases, owing to the short vertical distance intervening between the surface and the altitude of the observed wind, causes other than, or in addition to, rapid change in pressure gradient with altitude are to be inferred. Such instances are in fact observed in connection with nocturnal temperature inversions, from which circumstance a partial explanation is suggested to the effect that these "inversion" winds are due to a temporary interruption of the balance between pressure gradient and deflective forces, incident to the nocturnal contraction of the air column. An example is given in the two theodolite pilot balloon observation at Drexel on the 6th, in which the wind increased steadily from 1 meter per second on the ground to 26 meters per second at 3,100 meters above the ground. More pronounced examples are shown in the single theodolite pilot balloon observations (substantially verified by kite observations) at Due West on the 4th, and Ellendale on the 15th, where the wind velocity increased from 5 m. p. s. to 26 m. p. s. in the first 800 meters, and from 3 m. p. s. to 15 m. p. s. in the first 600 meters, respectively.

In contrast to the cases just cited, the following record of a two-theodolite pilot-balloon observation made at Royal Center on the 12th shows a peculiar wind structure with altitude. This record shows winds from a general westerly direction blowing at an almost uniform velocity of 4 m. p. s. throughout a depth of air column extending from 750 meters to 6,800 meters altitude.

Altitude, m. s. l. (meters)	225 (surface)	------	500	750	1,000	1,500	2,000	2,500	3,000
Wind direction and velocity, m. p. s	SW-2	------	W-3	W-4	SW-4	WSW-3	W-4	NW-4	WNW-4
Altitude, m. s. l. (meters)	3,500	4,000	4,500	5,000	5,500	6,000	6,800	------	------
Wind direction and velocity, m. p. s	W-3	W-3	W-4	NW-4	NW-4	W-4	W-4	------	------

This observation was made in the north portion of a crest of high pressure having an east-west axis, the weather map furthermore showing practically no horizontal surface temperature gradient within a few hundred miles range of territory. There was undoubtedly a uniform lapse rate in temperature with altitude for some distance in all directions from Royal Center and consequently a quite uniform slope of isobaric surfaces in the immediate vicinity of Royal Center throughout the range of altitude embraced by the observation.

In this connection it is of interest to note the pilot balloon observations at Groesbeck on the 20th, 21st, and 22d, which were made on the western side of an extensive high-pressure area. Winds from a southerly to southwesterly direction, and perhaps westerly in the higher altitudes, might be inferred from the pressure situation, inasmuch as the general trend of the isobars was southwest-northeast. Actually southerly winds prevailed to only moderate altitudes, above which east component winds, varying from northeasterly on the 20th to southeasterly on the 22d, were observed. East component winds to a considerable depth were also observed on a few dates at Due West, Broken Arrow, San Francisco, and Key West. In practically all these cases, similarly to that at Groesbeck just mentioned, the observations were made near the edge of high pressure areas, indicating the tendency at the more southerly stations to east component winds at high altitudes, a tendency that becomes more and more conspicuous, irrespective of the alignment of surface pressure gradients, as the warm season advances.

The record of the kite observation at Drexel on the 19th given in the following table, is cited to show that conditions in the free air preceding heavy showers by a few hours do not necessarily include high temperature lapse rates or high humidity.

Altitude, m. s. l.	Temperature	Relative humidity	Wind direction	Wind velocity
Meters	° *C.*	*Per cent*		*M. p. s.*
396 (surface)	25.2	48	SSW.	8
1,000	19.0	54	SSW.	11
1,500	15.8	54	SW.	10
2,000	13.2	48	WSW.	9
3,000	6.4	60	WNW.	11
4,000	0.0	44	NW.	12
5,000	−5.8	29	NW.	15
6,000	−11.3	24	NW.	17

It will be noted that the lapse rate averaged about 0.65° per 100 meters throughout the range of observation, and that only medium humidities prevailed. The observed lapse rate, however, was sufficient to cause

convection and precipitation as soon as humidity reached the saturation point, which condition was probably ultimately effected by accumulation from adjoining regions. A thunderstorm with 0.55 inch rainfall followed this observation by about 3 hours.

For comparison with the preceding case, the record of the fifth flight of the diurnal kite observation series of the 22d–23d at Drexel is referred to to show a free-air condition in which, by progressive fall in temperature aloft, a dry adiabatic lapse rate prevailed from 1,000 to 3,700 meters, but no precipitation resulted and weather remained practically cloudless for the following 12 hours. During this series precipitation occurred some distance east of Drexel, where the trend of the isobars indicated drainage from a more southerly source, while at Drexel the winds at intermediate levels were from dry regions to the west.

TABLE 1.—*Free-air temperatures, humidities, and vapor pressures during May, 1925*

TEMPERATURE (°C.)

Altitude m. s. l. (meters)	Broken Arrow, Okla. (233m.)		Drexel, Nebr. (396m.)		Due West, S. C. (217m.)		Ellendale, N. Dak. (444m.)		Groesbeck, Tex. (141m.)		Royal Center, Ind. (225m.)	
	Mean	Departure from 7-yr. mean	Mean	Departure from 10-yr. mean	Mean	Departure from 5-yr. mean	Mean	Departure from 8-yr. mean	Mean	Departure from 7-yr. mean	Mean	Departure from 7-yr. mean
Surface	18.9	−0.4	15.4	−0.4	20.4	0.0	13.7	+0.7	22.0	−0.6	15.4	−1.0
250	18.8	−0.4	------	------	20.0	−0.1	------	------	21.0	−0.7	15.1	−1.0
500	16.8	−0.5	14.7	−0.4	17.2	−0.6	13.3	+0.6	19.2	−0.7	12.1	−1.4
750	15.7	−0.1	13.3	−0.1	15.3	−0.7	11.6	+0.5	18.1	−0.5	10.3	−1.3
1,000	14.8	+0.2	12.1	+0.1	13.6	−0.9	10.3	+0.7	17.3	−0.1	8.9	−1.2
1,250	14.0	+0.6	11.0	+0.4	11.7	−1.3	8.9	+0.7	16.7	+0.3	7.4	−1.1
1,500	12.9	+0.7	9.6	+0.4	10.5	−1.1	7.2	+0.5	15.6	+0.3	5.8	−1.2
2,000	10.3	+0.7	6.8	+0.2	7.4	−1.6	3.7	0.0	13.5	+0.5	3.2	−1.2
2,500	7.3	+0.4	4.3	+0.4	4.8	−1.5	0.6	−0.1	10.5	+0.2	0.3	−1.6
3,000	4.4	+0.5	1.4	+0.4	1.4	−2.0	−2.0	+0.1	7.5	0.0	−2.8	−1.9
3,500	1.0	+0.1	−1.6	+0.3	−1.6	−2.2	−4.7	0.0	4.5	0.0	−6.6	−2.8
4,000	−2.3	+0.1	−4.2	+0.6	------	------	−8.0	− .3	1.7	+0.2	------	------
4,500	−4.9	+0.3	−6.8	+0.9	------	------	−11.6	−0.7	−0.9	+0.6	------	------
5,000	−7.1	+0.3	−9.5	+1.2	------	------	−15.4	−1.8	−2.6	+1.5	------	------

TABLE 1.—*Free-air temperatures, humidities, and vapor pressures during May, 1925*—Continued

RELATIVE HUMIDITY (%)

Altitude m. s. l. (meters)	Broken Arrow, Okla. (233m.)		Drexel, Nebr. (396m.)		Due West, S. C. (217m.)		Ellendale, N. Dak. (444m.)		Groesbeck, Tex. (141m.)		Royal Center, Ind. (225m.)	
	Mean	Departure from 7-yr. mean	Mean	Departure from 10-yr. mean	Mean	Departure from 5-yr. mean	Mean	Departure from 8-yr. mean	Mean	Departure from 7-yr. mean	Mean	Departure from 7-yr. mean
Surface	64	−7	59	−6	49	−14	52	−9	63	−8	58	−4
250	64	−7	------	------	50	−13	------	------	65	−6	58	−4
500	62	−7	58	−6	54	−10	52	−9	68	−4	61	−1
750	60	−9	55	−8	57	−8	51	−9	65	−6	63	+1
1,000	59	−9	55	−7	59	−6	51	−9	58	−10	63	+1
1,250	56	−10	54	−8	61	−4	51	−10	54	−10	65	+3
1,500	54	−10	54	−8	61	−4	52	−9	51	−9	66	+4
2,000	54	−8	55	−5	66	+3	57	−4	43	−10	68	+9
2,500	56	−3	55	−3	68	+6	57	−3	50	−1	75	+20
3,000	59	+3	53	−5	68	+10	50	−8	52	+2	74	+23
3,500	64	+8	56	−2	64	+11	44	−9	60	+11	92	+40
4,000	69	+11	60	+1	------	------	41	−10	67	+16	------	------
4,500	65	+9	58	−2	------	------	39	−12	74	+21	------	------
5,000	71	+9	58	−4	------	------	39	−9	86	+22	------	------

VAPOR PRESSURE (mb.)

Altitude m. s. l. (meters)	Broken Arrow, Okla. (233m.)		Drexel, Nebr. (396m.)		Due West, S. C. (217m.)		Ellendale, N. Dak. (444m.)		Groesbeck, Tex. (141m.)		Royal Center, Ind. (225m.)	
	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal	Mean	Departure from normal
Surface	14.31	−2.05	10.65	−1.18	11.78	−3.33	8.31	−0.98	16.69	−2.75	10.48	−1.25
250	14.17	−2.04	------	------	11.66	−3.19	------	------	16.21	−2.45	10.32	−1.20
500	12.45	−1.81	10.05	−1.13	10.73	−2.44	8.10	−0.94	15.17	−1.77	9.06	−0.79
750	11.17	−1.64	8.63	−1.20	10.12	−1.89	7.21	−0.75	13.70	−1.63	8.39	−0.36
1,000	10.44	−1.29	7.95	−0.94	9.53	−1.42	6.56	−0.65	11.51	−2.12	7.80	−0.08
1,250	9.55	−1.02	7.19	−0.87	9.00	−0.99	6.03	−0.59	10.04	−1.86	7.15	+0.05
1,500	8.55	−0.72	6.43	−0.84	8.47	−0.60	5.47	−0.54	8.77	−1.56	6.44	+0.09
2,000	7.23	−0.26	5.44	−0.34	7.68	+0.24	4.77	−0.08	6.50	−1.31	4.88	+0.01
2,500	6.09	+0.23	4.67	−0.01	6.91	+0.80	3.96	+0.13	6.06	−0.28	3.69	+0.08
3,000	5.30	+0.66	3.68	−0.11	5.51	+0.69	3.06	+0.06	5.22	−0.07	1.99	−0.50
3,500	4.56	+0.66	3.10	+0.06	3.97	+0.12	2.22	−0.02	5.25	+0.81	1.83	−0.16
4,000	3.96	+0.65	2.63	+0.17	------	------	1.71	0.00	4.68	+0.91	------	------
4,500	3.26	+0.55	1.95	−0.04	------	------	1.46	+0.14	4.58	+1.23	------	------
5,000	3.08	+0.55	1.56	−0.08	------	------	1.42	+0.41	4.76	+1.33	------	------

TABLE 2.—*Free-air resultant winds (m. p. s.) during May, 1925*

Altitude, m. s. l. (meters)	Broken Arrow, Okla. (233 meters)				Drexel, Nebr. (396 meters)				Due West, S. C. (217 meters)			
	Mean		7-year mean		Mean		10-year mean		Mean		5-year mean	
	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.
Surface	S. 26°E.	1.6	S. 22°E.	1.6	S. 12°W.	1.8	S. 10°W	1.1	N. 16°W.	1.2	N. 86°W.	0.3
250	S. 24°E.	1.5	S. 22°E.	1.6	--------	----	--------	----	N. 19°W.	1.2	N. 88°W.	0.4
500	S.	1.9	S. 10°E.	2.2	S. 11°W.	2.1	S. 14°W.	1.2	N. 62°W.	1.9	N. 87°W.	0.4
750	S. 15°W.	2.5	S.	2.6	S. 29°W.	2.3	S. 22°W.	1.3	N. 74°W.	2.4	S. 82°W.	1.4
1,000	S. 46°W.	2.9	S. 18°W.	2.8	S. 40°W.	2.3	S. 43°W.	1.9	N. 76°W.	2.7	S. 89°W.	1.9
1,250	S. 48°W.	2.9	S. 34°W.	3.0	S. 53°W.	2.0	S. 54°W.	2.2	S. 88°W.	3.6	S. 78°W.	3.0
1,500	S. 62°W.	3.7	S. 47°W.	3.4	S. 66°W.	3.4	S. 61°W.	3.1	N. 83°W.	4.6	S. 77°W.	4.1
2,000	S. 64°W.	4.2	S. 66°W.	4.1	S. 76°W.	3.8	S. 75°W.	4.2	N. 86°W.	6.7	S. 82°W.	5.5
2,500	S. 75°W.	4.7	S. 84°W.	5.2	S. 67°W.	4.7	S. 81°W.	4.9	N. 87°W.	11.9	S. 83°W.	7.1
3,000	N. 87°W.	4.6	N. 81°W.	6.2	N. 82°W.	7.0	S. 86°W.	7.1	N. 76°W.	11.9	N. 87°W.	6.9
3,500	N. 65°W.	5.6	N. 72°W.	8.5	N. 75°W.	10.2	N. 89°W.	8.4	W.	10.0	N. 83°W.	8.4
4,000	N. 78°W.	4.0	N. 69°W.	8.6	N. 69°W.	10.1	N. 81°W.	9.1	--------	----	--------	----
4,500	N. 67°W.	5.8	N. 65°W.	10.8	N. 54°W.	10.2	S. 85°W.	10.0	--------	----	--------	----
5,000	S. 89°W.	7.0	N. 61°W.	12.4	N. 51°W.	11.3	N. 78°W.	14.2	--------	----	--------	----

Altitude, m. s. l. (meters)	Ellendale, N. Dak. (444 meters)				Groesbeck, Tex. (141 meters)				Royal Center, Ind. (225 meters)			
	Mean		8-year mean		Mean		7-year mean		Mean		7-year mean	
	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.	Dir.	Vel.
Surface	S. 86°W.	1.5	N. 14°E.	0.4	S. 33°E.	1.9	S. 17°E.	2.0	S. 63°W.	1.7	N. 10°W.	0.2
250	--------	----	--------	----	S. 21°E.	2.8	S. 11°E.	2.6	S. 57°W.	2.0	N. 27°W.	0.1
500	S. 67°W.	2.0	N. 26°E.	0.2	S.	4.2	S. 3°E.	3.7	S. 64°W.	4.5	S. 63°W.	0.9
750	S. 43°W.	3.2	S. 11°E.	0.5	S. 6°W.	4.4	S. 7°W.	4.2	S. 70°W.	5.4	S. 70°W.	1.5
1,000	S. 59°W.	3.2	S. 7°W.	0.8	S. 15°W.	4.8	S. 19°W.	4.6	S. 76°W.	6.5	S. 84°W.	2.1
1,250	S. 77°W.	2.8	S. 26°W.	1.1	S. 14°W.	4.5	S. 27°W.	4.8	S. 45°W.	11.4	N. 86°W.	2.6
1,500	W.	2.6	S. 36°W.	1.4	S. 15°W.	3.4	S. 36°W.	4.6	S. 77°W.	6.4	N. 88°W.	2.8
2,000	N. 77°W.	4.5	S. 57°W.	2.4	S. 25°W.	3.5	S. 48°W.	4.6	S. 83°W.	19.7	W.	5.6
2,500	N. 75°W.	6.1	S. 62°W.	3.8	S. 16°W.	2.7	S. 63°W.	5.0	W.	13.1	N. 85°W.	5.1
3,000	N. 73°W.	9.0	S. 71°W.	5.3	S. 20°W.	3.0	S. 76°W.	6.1	N. 55°W.	16.9	N. 72°W.	6.7
3,500	N. 77°W.	9.4	S. 81°W.	5.8	S. 17°W.	3.5	S. 86°W.	7.0	N. 75°W.	15.4	N. 71°W.	7.6
4,000	N. 64°W.	13.6	N. 86°W.	7.1	S. 42°W.	2.6	N. 70°W.	9.6	N. 67°W.	19.1	N. 80°W.	7.2
4,500	N. 65°W.	11.5	N. 70°W.	5.7	S. 52°W.	2.2	N. 64°W.	9.4	--------	----	--------	----
5,000	W.	15.0	N. 6°W.	1.9	S. 22°E.	5.0	S. 80°W.	7.9	--------	----	--------	----

THE WEATHER ELEMENTS

By P. C. DAY, In Charge of Division

PRESSURE AND WINDS

The prominent features of the weather during May, 1925, were the rapid and frequently record-breaking changes in temperature during the early part of the third decade over many districts to eastward of the Rocky Mountains, and the continued widespread deficiency in precipitation over much of the same region, which has been more or less persistent since the beginning of the year.

The atmospheric circulation was on the whole rather sluggish for May and few cyclones were sufficiently active to cause important precipitation over widespread areas. In fact, due to rather persistent anticyclonic conditions over the central Great Plains and lower Missouri Valley districts, only two cyclones crossed the interior portions of the country, and these were not attended by widespread or generally heavy precipitation.

The first important cyclone of the month approached the middle Pacific coast about the 12th, attended by unusual precipitation for May over the central and northern portions of California. More or less rain fell over the middle plateau and Rocky Mountain regions as it moved southeastward to Colorado and New Mexico during the following two days. By the morning of the 16th the center was over eastern Iowa and the rainfall area had overspread the lower Missouri and upper Mississippi Valleys and portions of the Great Lakes. During the following 24 hours the storm moved to the St. Lawrence Valley, and precipitation was general over the Ohio Valley and North Atlantic States and also reached portions of the Middle Gulf States and Florida.

The second important storm of the month moved from western Canada to the vicinity of North Dakota by the morning of the 22d and thence southeasterly to the middle Atlantic coast during the following three days. This storm was attended mainly by scattered precipitation over the northern, central, and eastern districts, the rain turning to snow in some of the Northern States, due to a decided change to colder closely following the storm center.

The anticyclones were the important feature of the pressure distribution, and they were rather persistent over the interior portions of the country, causing marked changes to lower temperatures on several occasions.

For the month as a whole the pressure averaged highest over the middle Mississippi and lower Ohio Valleys, a condition not unusual, though the pressure over this and adjacent areas during May was distinctly higher than normal.

Generally speaking, the average pressure for May is everywhere normally less than for April in both the United States and Canada, save for a small area in extreme eastern New England and over the adjacent portions of Canada. During May, 1925, a large area over the interior portions of the country had mean pressure materially higher than in April preceding.

The presence of high pressure over the interior portions of the country favored southerly winds over the Great Plains and over many northern districts, while they were frequently from northerly points in the East Gulf States and from westerly directions along the Atlantic coast.

High winds were mainly of a local character and no severe storms affected large areas, caused unusual loss of life, or were attended by extensive damage to property. A list of those reported during the month follows at the end of this section.

TEMPERATURE

As stated at the beginning of this section, May, 1925, was notable for the wide extremes of temperature occurring during the month. It is not unusual for a single month to show temperature records either higher or lower than previously observed in that month or even show both extremes over limited and separate regions, but it is rare that these occur in the same month over identical extended areas, and rare indeed that they should occur over such areas within almost a few hours of each other, particularly in a late spring month, when the atmospheric circulation has largely assumed the quiet summer type.

During the period from the 22d to the 25th a cyclone of moderate proportions moved southeastward from the vicinity of North Dakota to the middle Atlantic coast. As barometric pressure was moderately high south of the storm center, warm winds from the South in conjunction with mainly clear weather immediately preceding the area of low pressure favored the occurrence of unusually high maximum temperatures, beginning on the 22d in the upper Mississippi Valley and continuing over the 23d and 24th in the regions to the south and east. During this period the highest temperatures ever observed in May or at least so early in the season were reported over extensive areas from the middle and upper Mississippi Valley eastward and southeastward to the middle Atlantic coast.

Immediately following this low-pressure area and its accompanying warmth, an anticyclone of the interior Canada type moved over nearly the same course, carrying the cold attending its origin quickly into the heated regions and causing marked and rapid changes in temperature. Over much of the region referred to the minimum temperatures attending the anticyclone were the lowest ever observed in May, or the lowest observed so late in the season.

In portions of the middle and upper Mississippi Valley, the changes from the extreme heat of the 22d to the marked cold of the 24th ranged up to nearly 80°, and in approximately 36 hours there were drops of from 60° to 65° in many cases.

Aside from the closely associated periods of warmth and cold referred to above, cool weather for the season prevailed during the first few days of the month over most districts from the Rocky Mountains eastward. Cool weather for May prevailed in the upper Missouri Valley about the end of the first decade, when temperatures at points in Montana were 10° or more below freezing and as low as ever experienced so late in spring. Temperatures were also unusually low in the Dakotas on the 16th, and some unusually high temperatures occurred in the same area on the 30th.

For the month as a whole there was a sharp change from the unusual warmth that had prevailed from February to April, inclusive, over the districts from the Rocky Mountains eastward, the averages for May ranging from 2° to 6° below the normal over much of the eastern half of the country. West of the Rocky Mountains the monthly temperatures continued above the normal, as has been the case since the beginning of the year, and at a few places the means were the highest ever observed in May.

Maximum temperatures were as high as 100°, or more, over much of the interior and southern parts of the

country, reaching extremes of 111° in North Dakota and 115° in Texas.

Minimum temperatures were freezing or lower at some time during the month in all the States except a few in the extreme Southeast. The lowest reported was 7° in the mountain regions of Wyoming, and a reading as low as 38° was recorded in northern Florida.

Frosts were frequent during the month over most central and northern districts east of the Rocky Mountains and the generally cool conditions retarded the season's progress, the early advance of which, brought about by the warmth of preceding months, had been partially lost by the end.

PRECIPITATION

May, 1925, like the four preceding months, was greatly deficient in rainfall as compared with the normal over much of the country, and at the close many sections were suffering severely from lack of moisture. In the upper Mississippi Valley and adjacent portions of the Great Lakes region the rainfall was frequently the least of record in May, observations extending back from 50 to 75 years. Similar conditions, though less pronounced, prevailed in many parts of the cotton belt. Over much of the interior of the country the deficiencies for the three spring months have been large and the total precipitation has been the least ever known for those months, while in other cases all five months of the present year have shown marked deficiencies and the total fall from January to May, inclusive, has been less than ever before received during those months. On the other hand, in the far West, notably in California, where precipitation was greatly deficient during the earlier months of the rainy season, the falls were more generous and at points in the vicinity of San Francisco the month as a whole received the heaviest falls in May since 1849, when observations first began. Considerable damage from the unusual rainfalls so late in the season resulted to hay and some early fruits, but otherwise they were of much benefit.

In portions of Texas where drought had persisted for long periods, heavy rains brought some relief about the end of the first decade and again at the end of the month. Also in northern Florida and adjacent sections where locally drought had existed since the middle of March some relief was afforded by occasional showers, but the deficient rainfall of preceding months caused unusually dry conditions at the end.

Considering the States as a whole only Florida, New Mexico, California, and Oregon had monthly falls in excess of the normal, all other States showing deficiencies, these being particularly large in the States bordering on the Mississippi River.

SNOWFALL

In California some snow fell in the higher mountains, the total falls for the month ranging up to nearly 3 feet in favorable localities, but practically all snow had melted by the end of the month.

There were moderate falls in the higher ranges of the Rockies from Colorado northward, and light falls along the northern border and over the Appalachian Mountain districts from Virginia northward. The latter falls were mainly associated with the cold period near the middle of the last decade. In parts of western Pennsylvania depths ranging from 3 to 6 inches were measured, breaking all May precedents both in amounts and lateness of occurrence. Some snow fell at the higher elevations in the vicinity of Northfield, Vt., on the 25th, the latest of record for that locality.

Snow was observed at La Crosse, Wis., on the 24th and 27th, at Port Huron, Mich., on the 24th, and at Parkersburg, W. Va., on the 25th, all the latest of record. At Seattle, Wash., snow occurred on the 2d, the only record of snow in May at that place.

RELATIVE HUMIDITY

As a result of the generally dry condition existing during much of the month the relative humidity was less than normal over nearly all portions of the country, the notable exceptions being the greater part of California, and locally in the middle plains, and New England, where there were slight to moderate excesses.

SEVERE LOCAL HAIL AND WIND STORMS, MAY, 1925

[The table herewith contains such data as have been received concerning severe local storms that occurred during the month. A more complete statement will appear in the Annual Report of the Chief of Bureau]

Place	Date	Time	Width of path (yards) [1]	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Cleveland, Ohio	3	7.17 p. m.			$50,000–75,000	Thunderstorm	Tower of church damaged; windows broken; 11 persons injured.	Official, United States Weather Bureau.
Terre Haute, Ind	4	11.45 a. m. 12.55 p. m.				Thunderstorm and hail.	Tomato and cabbage plants beaten; grape vines and trees injured.	Do.
Parkersburg, W. Va	4	1.30 p. m.	880		500	Heavy hail	Gardens and fruit trees considerably damaged. Path 6 miles long.	Do.
Newton, Utah	7		1,760			do	Damage principally to alfalfa and beets. Young chickens killed. Path 6 to 7 miles long.	Do.
San Antonio, Tex. (vicinity of).	8	P. m.			60,000	Thunderstorm	Stinson Flying Field completely wrecked. Minor damage in other sections.	Do.
Trementina, N. Mex	9					do	100 head of cattle killed	Do.
Kenner, La	10	8–9 a. m.	400			Wind	Trees torn up; roof damaged; ferry boat and landing torn loose.	Do.
Cloutierville, La	11	5.30 p. m.				Heavy hail	Several hundred acres of corn and cotton destroyed.	Do.
Quincy, Fla. (near)	12	3–4 p. m.	6 mi		12,000–18,000	do	Corn, cotton, and truck damaged	Do.
Ford and Clark Counties, Kans.	12	5–6 p. m.	2–10 mi.		50,000	Hail	Growing wheat damaged 25 per cent to total	Do.
Harper County, Okla. (northern part of).	12	8–9 p. m.	10 mi			Severe hail	Great damage to crops	Do.
Paducah, Tex	13	4 a. m.	15–20 mi.		10,000	Hail	Light buildings, crops, and windmills damaged; path 30 miles.	Do.
Rogers, Ark. (w. and n. of)	13		2–3 mi			Heavy hail, wind and rain.	Orchards and gardens considerably injured	Do.
Springfield, Mo. (11 miles se. of).	13	10 a. m.				Heavy hail	do	Do.
Deaver, Wyo	14	1.20–2 p.m.	2,640		5,000	do	Sugar beets, gardens, and alfalfa injured; irrigating canal damaged.	Do.

[1] mi. signifies miles instead of yards.

Severe local hail and wind storms, May, 1925—Continued

Place	Date	Time	Width of path (yards)	Loss of life	Value of property destroyed	Character of storm	Remarks	Authority
Haskell County, Kans	14	6.30 p. m	1.5-2 mi		40,000	Hail	Damage principally to growing wheat	Official, United States Weather Bureau.
Ford County, Kans	14	8 p. m			25,000-50,000	do	do	Do.
Lane County, Kans	14	9 p. m	2 mi		100,000	do	do	Do.
Pawnee County, Kans	14	12.30 a. m.	2.5 mi		75,000-100,000	do	do	Do.
Chanute, Kans	15					Violent wind	Barns unroofed, residences and garages damaged; wire service crippled.	Do.
Salt Lake City, Utah, and vicinity.	15	5.25 p. m				Thunderstorm	Minor property damage; streets flooded.	Do.
Norman, Okla	15	5.30-7 p. m.	1,760		250,000	Wind	Heavy property damage; crops hurt; 3 persons injured.	Do.
Byron, Ind. (near)	16					Severe wind	Many trees wrecked; buildings damaged	Do.
Mazon, Ill. (near)	16				10,000	Wind	Farm buildings damaged	Do.
Missouri	16				150,000	Wind, rain, and hail.	Considerable damage throughout State; Booneville and Columbia hardest hit.	Do.
Attica (near) to Pittsfield (near), Ohio.	16		25-440			Tornado	Much damage in area covered; damage at Pittsfield estimated at $100,000. A number of persons were injured.	Do.
Arkadelphia, Ark. (4 miles se. of).	17		880			Heavy hail	All crops ruined in areas covered	Do.
Laporte, Ind. (vicinity of)	17					Tornado	Many farm buildings wrecked	Do.
Houghton, Mich	19					Thunderstorm	Wires down; barn and contents burned	Do.
Ehrhardt, S. C	19					Severe hail	Young crops badly injured	Do.
Mokelumne Hill, Calif	19	5.30 p. m	4-5 mi			Heavy hail	Fruit trees damaged about 65 per cent; tomatoes and grapes injured.	Do.
Fresno, Calif	19	10.15-10.20 p. m.	3,520			Moderate hail	Fruit bruised; path 15 miles long	Do.
Hanford, Calif	19	10.30-11 p. m.	880			Heavy hail	Minor damage reported	Do.
Clovis, Calif	19	11.10-11.45 p. m.	10 mi			do	Damage considerable in some places, severe in others.	Do.
Sioux City, Iowa, and vicinity	19	8-9 p. m	10 mi		30,000	Hail and rain	Greenhouses badly damaged; some damage by flooding.	Tribune (Sioux City, Iowa).
Dawson County, Nebr	20	P. m.	3-4 mi			Hail	Truck, small grains, and alfalfa injured	Official, United States Weather Bureau.
Deaver, Wyo	20	6.20-8 p. m.			2,000	Wind	Farm buildings damaged	Do.
Boone County, Nebr	20	7 p. m	880			Hail	Growing crops damaged	Do.
Butler County, Nebr	20	7.30 p. m	880-1,760			do	Crops damaged	Do.
Dodge County, Nebr	20	9.30-10.30 p. m.	6 mi		17,000	do	Crops injured; some damage to greenhouses	Do.
Boulder, Colo	21	3.30-4.30 p. m.		1		Wind	Telephone, telegraph, and power lines crippled	Do.
Greeley, Colo	21	4.30 p. m		1		do	Many barns and other farm buildings destroyed; electric lines seriously damaged; poultry killed, minor crop injury.	Do.
Terre Haute, Ind	21	1.30 p. m			1,500-2,000	Wind and hail	Some fruit bruised, small plants beaten, and much glass broken.	Do.
Crawfordsville, Ind. (w. of)	21				5,000	Tornado	Buildings in path damaged	Do.
Southern Illinois	21	P. m.		3		Wind, rain and hail.	A number of houses damaged; communication interrupted; trees blown down.	Daily News (Chicago, Ill.).
Minnesota and South Dakota (parts of).	22	P. m			500,000	do	Scores of barns, houses, silos, and windmills blown down; cattle and horses killed; wires down.	Evening Huronite (Huron, S. Dak.).
Hutchinson, Kans	23	2.30 a. m	4 mi			do	Growing wheat, fruit, and gardens suffer considerably; some damage to greenhouses.	Official, United States Weather Bureau.
Essex and Passaic Counties to Bergen County, N. J.	23					Wind and hail	Damage principally to crops	Do.
Greenwich, Conn	23					Hail	No material damage reported	Do.
Mount Vernon, N. Y	23	2.50-3.10 p. m.			10,000	Moderate hail	Garden truck, hotbeds, and auto tops damaged	Do.
Scarsdale, N. Y	23	4 p. m				do	do	Do.
Franklin, Pa	23	4 p. m.			60,000	Severe hail and wind.	Several buildings partially wrecked; heavy damage to crops and greenhouses; 1 person injured.	Do.
Cuyahoga County, Ohio (n. part of).	23	4 p. m				Thunderstorm and hail.	Heavy damage to crops, fruit and greenhouses	Do.
New York City, N. Y. (vicinity of).	23	6-7.30 p. m.	20 mi	2	250,000	High wind and heavy hail.	Trees uprooted; signs torn down, auto tops ruined; damage principally to greenhouses on north shore of Nassau County.	Do.
Bridgehampton, N. Y	23	7 p. m				Moderate hail	Garden truck and windows damaged	Do.
Cutchogue, N. Y	23	8 p. m	1,760			do	do	Do.
Carlisle, Pa. (near)	23					Violent wind and thunderstorm.	Considerable minor damage to biuldings	Do.
Barbour, Taylor, Randolph, and Tucker Counties, W. Va.	24	2 p. m		3	45,000	Destructive wind and heavy hail.	Greatest property damage at Valley Bend and Huffman; roofs, windows, and small buildings damaged; two barns destroyed.	Do.
Northern Howard and Anne Arundel Counties to southeastern Baltimore County, Md.	24	3.50-6.00 p. m.	12 mi		75,000	Heavy hail	Greenhouses and crops damaged; other vegetation injured; traffic delayed; path 18 miles long.	Do.
Porter, N. Mex. (near)	24	6.30-7 p. m.	2 mi			do	Fruit and forest trees damaged; minor crop injury.	Do.
Lubbock, Tex. (vicinity of)	24		1,760			Hail	All cotton near station killed; minor damage elsewhere.	Do
Fleming County, Ky	24		880			Hail and wind	Crops and gardens totally destroyed by hail; 40 barns blown down; path 3 miles long.	Do.
Laramie, Wyo. (near)	26	3.30-3.45 p. m.				Tornado and hail	No damage, as storm passed over open country.	Do.
Scotts Bluff County, Nebr	27	2.30-4 p. m.	3 mi			Hail	Winter wheat and alfalfa badly damaged	Do.
Gloucester County to Ocean County, N. J.	29					do	Some fields and cranberry bogs almost totally damaged.	Do.

STORMS AND WEATHER WARNINGS

WASHINGTON FORECAST DISTRICT

The month as a whole was a very quiet one so far as storm warnings were concerned. Only two were issued, namely, on the 17th from Delaware Breakwater to Eastport and on the 25th from Sandy Hook to Boston. Small-craft warnings were ordered on the 23d and advices disseminated by radio on the 24th for strong winds off the middle and north Atlantic coast.

Frost warnings were ordered on the following dates: 1st, 2d, 5th, 7th, 8th, 11th, 12th, 14th, 15th, 17th, 18th, 25th, and 26th, mostly for the lower Lake region and interior of the Middle Atlantic States. Frosts occurred in substantial agreement with the warnings.

Numerous records for low and also for high temperature for the season were broken. These are referred to in greater detail under "The weather elements" (pp. 232–233).—*R. H. Weightman.*

CHICAGO FORECAST DISTRICT

The month, as a whole, was unusually dry throughout the forecast district, and the temperature was below normal from the eastern limits of the district westward to the central portion of the Plains States. In the middle Rocky Mountain region it was considerably above the seasonal normal. The drought was really the most important meteorological factor during the month.

At the beginning of the month the weather was rather cool with frosts over most of the forecast district, and warnings for additional frosts were issued on the morning of the 1st from the upper Mississippi Valley eastward, and these were generally verified.

On the morning of the 3d a cold, high area of considerable magnitude appeared in British Columbia, and this gradually pushed eastward and southeastward during the next five days, accompanied by general frosts, for which warnings were issued well in advance.

Another such area, but of less importance, first came to view in the Canadian Northwest on the morning of the 9th, and this took a southeasterly direction, finally reaching the central valleys on the 11th and 12th. Frosts also accompanied the movement of this high, and warnings were issued in anticipation of their occurrence. Another high-pressure area immediately followed, appearing first in Manitoba on the 13th and crossing the Great Lakes region on the 14th and 15th, with some frosts in that area, the usual warnings being given; and so with still another high which crossed the upper Mississippi Valley and the Great Lakes on the 17th and 18th.

The principal atmospheric disturbance of the month appeared in the Plateau region on the 20th. It first took a northeasterly course to Manitoba and then southeasterly across the upper Mississippi Valley, southern Lake region and Ohio Valley, and was succeeded by a cold, high area of great magnitude. The temperature rose rapidly in front of the disturbance, and maxima far above 90° were reached generally throughout central districts on the 22d. With the movement southeastward of the low forced rapidly by the northern high, a decided break occurred generally throughout middle districts on the 23d and 24th, with strong northerly winds, reaching gale force at several places. The temperature within the brief period of 24 hours, after having reached record-breaking high marks for so early in the season, fell to record-breaking minima for so late in the season

The attendant frosts were quite general and "heavy" to "killing" in localities, resulting in great damage to crops, tender vegetation, and fruit. Warnings of frost had been issued to the entire area, as well as warnings of storm winds on the Great Lakes. Other warnings, chiefly small craft, were issued for the Great Lakes during the month, but as a rule the storms were not of much importance.

The usual special frost warnings were sent to the cranberry marshes of Wisconsin with, doubtless, beneficial results.

Special 3-day forecasts were furnished daily to the fruit interests of southwestern lower Michigan and to Door County, Wis., in connection with spraying operations, etc.

Fire-weather warnings were continued during the month to the State forester at St. Paul, Minn., who in a letter to this office dated June 8 expresses his appreciation of the special forecasts, as follows:

> The forecasts have been a wonderful assistance to us during the spring season. The information was distributed by wire to all our rangers daily when conditions looked unfavorable. We appreciate very much the assistance you have given us by sending these forecasts, and this opportunity is taken to express our greatest thanks.

In connection with the military tournament held in Chicago in the Grant Park Stadium on May 22, 23, and 24, it was planned by the Army to bring a large dirigible balloon from Scott Field, but, upon the advice of the forecaster that squally and stormy conditions were impending, the trip was abandoned. The officer in charge expressed personally his appreciation of the service.—*H. J. Cox.*

NEW ORLEANS FORECAST DISTRICT

Frost warnings were issued for the northern portion of the district on the 1st, 4th, and 25th, and frost occurred in some localities on the dates following in each instance. No storm warnings were issued during the month except that small-craft warnings were displayed at Corpus Christi on the 25th. No general storm occurred on the West Gulf coast.—*I. M. Cline.*

DENVER FORECAST DISTRICT

Although low pressures persisted over the Southern Plateau sections and Arizona during nearly all of the month, there was a continued deficiency in precipitation in about all of the district except New Mexico. Temperatures were generally considerably above normal. A showery period began in Colorado and New Mexico on the 5th and continued until the 11th. Showers also fell in Colorado and Utah on the 15th and 16th, in the northern and eastern portions of the district on the 20th and 21st, in eastern Colorado on the 25th, in Colorado and New Mexico from the 26th to the 31st, and in Utah on the last-named date. The amounts, however, were generally light. Highs of considerable intensity prevailed on the northeastern Rocky Mountain slope and in the upper Missouri Valley from the 3d to the 10th, with freezing weather in extreme northeastern Colorado on the mornings of the 4th, 5th, and 9th. Temperatures below freezing in most of northeastern Colorado on the morning of the 1st attended a high that was advancing across the Missouri Valley.

Frost warnings, which were generally justified, were issued as follows: 4th, heavy frost eastern, freezing temperature northeastern Colorado; 5th, frost northeastern

Colorado; 12th, frost western valleys of Colorado and extreme north-central and extreme northwestern New Mexico; 14th, frost southwestern Colorado valleys, extreme northwestern New Mexico and extreme southern Utah; 22d, frost extreme southwestern Colorado, extreme northwestern New Mexico, and northeastern Arizona.

The following fire-weather warnings were issued: 7th, strong shifting winds in New Mexico, Arizona, and Utah; occasional showers probable in New Mexico, northeastern Arizona, and southeastern Arizona; 31st, strong southwest winds indicated in northern and eastern Arizona, New Mexico, and southern Utah; local showers probable in Utah. The conditions that followed justified the issue of the warnings.—*J. M. Sherier.*

SAN FRANCISCO FORECAST DISTRICT

The feature of prominence as disclosed by the daily weather charts was the presence, rare for the month of May, of well-defined cyclonic areas on two occasions over the ocean off the California coast. The first of these apparently formed off the coast preceding the 10th and caused rains in California from the 10th to 13th and another formed off the coast on the 14th and 15th and caused general rains over the same State from the 16th to the 20th. The rains were detrimental to some of the fruits and to newly-mown hay; otherwise they were beneficial. In the aggregate the benefit from the rains more than offset the damage done. Forecasts of their occurrence were accurate as to time and place. The precipitation in the San Francisco Bay region was unusually heavy and brought the catch of rainfall for the season well above the normal and produced at San Francisco the heaviest May rainfall since the record began in 1849. It is not possible to say whether the cyclonic areas actually formed off the coast or whether they moved southeastward from the Gulf of Alaska. The Pacific high on these two occasions was displaced far to the westward of its normal position, being centered north of the Hawaiian Islands, and this may have permitted both storms to advance southeastward along the eastern and northeastern periphery of the anticyclone.

No storms accompanied by winds of exceptional force occurred along the coast until the night of the 27th, when south winds of gale force were reported from the Washington-Oregon coast. Storm warnings were displayed at northern ports on the morning of the 27th.

As typifying the requests for meteorological information that come to a district forecast center, the following is an example. In the Imperial Valley large quantities of cantaloupes are raised for shipment, largely to eastern markets. The output this year, it is stated, will reach 15,000 carloads. On the 14th of May the following telegram was received:

ELCENTRO (IMPERIAL VALLEY), CALIF.,
May 14, 1925.

OBSERVER, U. S. WEATHER BUREAU,
San Francisco, Calif.

Recent high humidity with fairly warm temperatures has resulted in serious outbreak of mildew on cantaloupe vines. Unless low humidity or temperatures exceeding 100° occur in next two days growers will have to spray. Growers anxious to know whether you forecast low or high humidity or very hot weather for Imperial Valley in next two or three days. Wire reply.

(Signed) E. GARTHWAITE.

The following telegram was sent in reply:

Neither very high temperatures nor very low humidity indicated next two or three days. Advise spraying.

BOWIE.

Conditions that followed were favorable to the spread of mildew.

There were no frosts of consequence during the month, except in the more northern part of this forecast district. The fruit belts of Washington and Oregon were kept advised from day to day as to what to expect in the way of low temperatures with reference to the firing of orchards.

No general fire-weather warnings were issued during the month, although on several occasions when low humidity was expected advices to exercise caution in slash burning were issued for Washington and Oregon.—*E. H. Bowie.*

RIVERS AND FLOODS

By H. C. FRANKENFIELD

Excepting that in the Rio Grande of Texas, no floods of consequence occurred during May, 1925. The rise continuing from late April in the Sulphur River was attended by comparatively small crop losses and a saving, through Weather Bureau warnings, of property valued at about $10,000; while in the Trinity River flood no movable property was reported lost and the saving of property through the warnings was estimated at $22,500. Prediction of both floods was timely and accurate.

In the more severe rise in the Rio Grande, which resulted from excessive rains over southwest Texas on May 27, 28, and 29, flood stage was passed at all gaging stations on the river, six lives were reported by newspapers to have been lost, bridges were washed out, levees broken, houses destroyed, livestock drowned, and crops ruined. Total reported losses were as follows: Bridges and tangible property, $30,000; livestock, $15,000; growing crops, $20,000. No estimate has been received of the value of property saved through Weather Bureau warnings, but these were accurate and issued well in advance of the flood and are known to have resulted in a large saving of movable property and livestock.

The spring rise in the Colorado River passed off without reported damage, flood stage occurring at only two stations.

The spring rise of the Columbia River was still in progress at the close of the month. Report thereon will be made in the MONTHLY WEATHER REVIEW for June, 1925.

Rivers of the Mississippi system were unusually low for the time of year, but as this condition continued during the succeeding month more detailed mention thereof will be deferred until the June report.

River and station	Flood stage	Above flood stages—dates		Crest	
		From—	To—	Stage	Date
MISSISSIPPI DRAINAGE	*Feet*			*Feet*	
Sulphur:					
Ringo Crossing, Tex	20	(1)	1	23.4	Apr. 28
Finley, Tex	24	3	7	25.0	May 4, 5
WEST GULF DRAINAGE					
Trinity:					
Dallas, Tex	25	7	13	[2] 34.6	11
Trinidad, Tex	28	13	19	35.3	17
Trinity (Elm Fork), Carrollton, Tex	7	10	10	7.8	10
Rio Grande:					
Del Rio, Tex	10	28	30	23.2	29
Eagle Pass, Tex	16	28	30	33.7	30
Laredo, Tex	27	31	31	29.0	31
Rio Grande City, Tex	15	31	(3)	-------	-------
COLORADO DRAINAGE					
Colorado:					
Lees Ferry, Ariz	12	22	(3)	13.2	28
Parker, Ariz	7	25	(3)	8.2	31
PACIFIC DRAINAGE					
Columbia:					
Marcus, Wash	24	16	(3)	30.4	26
Wenatchee, Wash	40	24	(3)	40.8	28
Vancouver, Wash	15	16	(3)	21.5	25, 26
Kootenai, Bonners Ferry, Idaho	26	20	28	29.4	24
Pend O'Reille, Newport, Wash	16	21	(3)	19.9	31
Clearwater, Kamiah, Idaho	14	20	20	14.1	20
Willamette, Portland, Oreg	15	16	(3)	21.7	26

[1] Continued from last month.
[2] Estimated.
[3] Continued at end of month.

MEAN LAKE LEVELS DURING MAY, 1925

By UNITED STATES LAKE SURVEY

[Detroit, Mich., June 5, 1925]

The following data are reported in the "Notice to Mariners" of the above date:

Data	Lakes [1]			
	Superior	Michigan and Huron	Erie	Ontario
Mean level during May, 1925—	*Feet*	*Feet*	*Feet*	*Feet*
Above mean sea level at New York	600.94	578.42	571.30	245.65
Above or below—				
Mean stage of April, 1925	+0.09	+0.07	−0.05	+0.04
Mean stage of May, 1924	−0.20	−0.82	−0.86	−0.45
Average stage for May, last 10 years	−1.04	−2.06	−1.25	−0.72
Highest recorded May stage	−2.11	−5.10	−3.12	−3.30
Lowest recorded May stage	+0.12	−0.82	−0.01	+0.69
Average relation of the May level to—				
April level	-------	+0.3	+0.4	+0.4
June level	-------	−0.2	−0.2	−0.2

[1] Lake St. Clair's level: In May, 1925, 573.74 feet.

EFFECT OF WEATHER ON CROPS AND FARMING OPERATIONS, MAY, 1925

By J. B. KINCER

General summary.—The weather conditions during May were largely unfavorable for most crops in much of the country. There were wide fluctuations in temperature, particularly during the latter part of the month when an abrupt change from record-breaking warmth for the season to damaging frosts was decidedly unfavorable. There was considerable harm done by the cool wave to tender vegetation and small fruits in the North Central States, with more or less damage to corn in some localities, and all vegetative growth was set back materially.

The cool wave did not reach the Southern States and middle Atlantic area with markedly harmful effect, although the growth of crops was checked. At the close of the month, however, seasonable warmth prevailed and conditions had improved considerably, though there was a widespread need for moisture over the eastern half of the country. In the more western States moisture conditions were generally favorable, except in the Southwest where severe drought continued in most districts.

Small grains.—Winter wheat made fair to very good progress in the principal producing sections during the first half of the month, with beneficial showers in the eastern portion of the belt. The latter part was much less favorable, however, as it was too cool and dry in the eastern wheat States, and there were complaints of dry and too warm weather in the southwestern portions of the Wheat Belt. There was some frost damage in a few localities, and the crop quite generally headed short because of deficient moisture, while insects and disease were harmful in Kansas. Spring wheat made fairly good advance, though it was somewhat too cool for rapid growth, and more moisture was needed in some localities. In most of the Spring Wheat Belt, however, the conditions were favorable, especially in the heavy producing sections of North Dakota. The weather was mostly unfavorable for oats because of insufficient moisture, and at the close of the month the crop was heading short.

Corn.—There was some delay in corn planting in the upper Mississippi Valley by reason of dry soil and cool weather, but planting made fairly good advance in most districts. Germination and growth were slow, however, especially in the eastern and central portions of the Corn Belt. Conditions were more favorable in the Great Plains States. Corn was considerably cut back by frost in some of the interior States, but it recovered nicely with the return of warmer weather.

Cotton.—The rainfall about the middle of the month in the central and eastern portions of the Cotton Belt was very beneficial, and considerable seed that had lain dormant for some time germinated with the increased moisture, while rains in Texas earlier in the month were helpful. Part of the month was too cool for cotton in the northern portions of the belt, and the late-planted cotton again needed moisture in some districts during the latter part, particularly so in southern Texas. On the whole the weather was favorable for cotton, and at the close of the month the crop was generally in satisfactory condition.

Miscellaneous crops.—Truck and garden crops suffered severely from the freeze in many interior and northern districts, but these made fairly good progress in other sections of the country. At the close of the month potato planting was well advanced in the Northeastern States, but growth was slow in the interior valleys because of coolness. Tobacco setting was retarded by dry weather in the Ohio Valley, and the transplanting of sweet potatoes was hindered in the Southeast by the same cause. Pasture lands and meadows were unfavorably affected in most of the eastern half of the country, but in the Northwest and Central-Western States conditions were favorable for the range and livestock. It was too dry for grazing interests in the Southwest.

CLIMATOLOGICAL TABLES[1]

CONDENSED CLIMATOLOGICAL SUMMARY

In the following table are given for the various sections of the climatological service of the Weather Bureau the monthly average temperature and total rainfall; the stations reporting the highest and lowest temperatures, with dates of occurrence; the stations reporting the greatest and least total precipitation; and other data as indicated by the several headings.

The mean temperature for each section, the highest and lowest temperatures, the average precipitation, and the greatest and least monthly amounts are found by using all trustworthy records available.

The mean departures from normal temperatures and precipitation are based only on records from stations that have 10 or more years of observations. Of course, the number of such records is smaller than the total number of stations.

Condensed climatological summary of temperature and precipitation by sections, May, 1925

Station	Temperature								Precipitation					
	Section average	Departure from the normal	Monthly extremes						Section average	Departure from the normal	Greatest monthly		Least monthly	
			Station	Highest	Date	Station	Lowest	Date			Station	Amount	Station	Amount
	°F.	°F.		°F.			°F.		In.	In.		In.		In.
Alabama	70.3	−1.3	Florence	99	31	2 stations	33	[2] 1	2.36	−1.79	Spring Hill	5.58	Tuskegee	0.06
Alaska (April)	34.5	+1.4	Fortmann Hatchery	60	15	Broad Pass	−17	13	3.88	−0.48	Ketchikan	11.98	Fort Yukon	T.
Arizona	70.0	+3.6	2 stations	108	[2] 25	Alpine	13	11	0.18	−0.13	Mount Graham Mill	2.02	38 stations	0.00
Arkansas	68.0	−1.2	Helena	102	30	Dutton	26	1	1.88	−3.24	Yancopin	5.58	Searcy	0.25
California	62.4	+1.8	Greenland Ranch	113	[2] 25	Helm Creek	16	14	1.77	+0.67	Big Sur	6.97	8 stations	0.00
Colorado	55.5	+3.7	2 stations	103	[2] 20	Dillon	15	1	1.41	−0.40	Crested Butte	4.61	Delta	0.23
Florida	74.0	−1.6	3 stations	96	[2] 11	Mount Pleasant	38	2	6.03	+1.69	Miami No. 2	18.74	Mount Pleasant	0.93
Georgia	70.3	−1.7	Brooklet	100	23	Blue Ridge	28	2	1.80	−1.59	Valdosta	4.31	Griffin	0.47
Hawaii	71.2	−0.3	Mana Pump	89	[2] 7	2 stations	49	[2] 10	4.90	−2.03	Eke	25.00	10 stations	0.00
Idaho	57.0	+3.9	Chattin Flat	95	18	Salmon	18	9	1.39	−0.24	Glenns Ferry	3.57	Chattin Flat	0.09
Illinois	59.3	−3.4	Danville	103	22	Mount Carroll	25	25	1.38	−2.85	Dwight	3.67	2 stations	0.22
Indiana	58.2	−4.1	Huntingburg	97	22	2 stations	26	25	1.32	−2.80	Mauzy	3.40	Delphi	0.18
Iowa	57.8	−2.4	2 stations	102	22	Milford	20	17	1.16	−3.45	Mount Pleasant	2.62	2 stations	0.30
Kansas	62.9	−0.2	do	104	21	2 stations	23	1	2.16	−1.63	Syracuse	5.21	Plains	0.30
Kentucky	61.2	−4.4	Hopkinsville	98	31	Farmers	28	8	2.58	−1.39	Ravenna	4.95	Earlington	0.77
Louisiana	72.5	−1.4	2 stations	98	30	Delhi	30	2	2.60	−1.73	Pearl River	7.50	Logansport	0.70
Maryland-Delaware	59.0	−3.9	do	100	23	Oakland, Md	25	27	1.88	−1.70	Friendsville, Md	3.47	Millsboro, Del	0.66
Michigan	50.7	−2.9	Cassopolis	105	23	Sidnaw	14	24	1.02	−2.26	Deer Park	3.17	Roscommon	0.15
Minnesota	52.8	−1.7	3 stations	100	22	Pine River Dam	13	6	1.55	−1.74	Crookston	4.60	Virginia	0.30
Mississippi	70.6	−1.0	2 stations	98	[2] 23	University	32	1	3.76	−1.43	Bay Saint Louis	14.26	Grenada	0.34
Missouri	61.2	−3.4	do	98	[2] 21	Unionville	24	2	2.14	−2.56	Kansas City	5.49	Greenville	0.58
Montana	54.4	+2.9	3 stations	98	[2] 21	Browning	10	10	1.36	−0.86	Adel	4.16	2 stations	T.
Nebraska	58.7	−0.3	Falls City	104	22	Gordon	15	1	2.06	−1.49	Upland	4.95	Butte	0.51
Nevada	60.5	+4.0	Logandale	102	28	Rye Patch	17	8	0.85	−0.08	Lamoille	2.58	2 stations	0.00
New England	52.3	−2.4	Norwalk, Conn	90	23	3 stations	22	[2] 9	2.48	−0.93	Somerset, Vt	4.58	do	1.18
New Jersey	57.7	−2.6	Indian Mills	99	23	Runyon	23	8	2.86	−0.93	Belvidere	4.94	Cape May City	0.49
New Mexico	62.7	+3.0	4 stations	102	[2] 19	Lee's Ranch	18	[2] 2	1.29	+0.19	Amistad	5.48	Farmington	0.00
New York	52.0	−4.1	West Point	96	23	Bolivar	19	7	2.74	−0.81	Bolton	6.62	Lauterbrunnen	0.24
North Carolina	63.5	−2.9	Greenville	99	23	Parker	20	26	2.80	−1.27	Sanatorium	7.01	Hatteras	0.72
North Dakota	53.6	+1.0	Westhope	111	30	Hansboro	10	16	1.44	−1.11	Finley	4.85	Foxholm	0.38
Ohio	55.6	−5.2	Jackson	95	23	2 stations	26	25	2.61	−1.11	Ironton	4.53	Bowling Green	0.76
Oklahoma	68.0	+0.3	Hooker	105	20	3 stations	30	1	2.38	−2.24	Norman	8.74	Broken Bow	0.15
Oregon	57.2	+3.2	McMinnville	94	5	Fremont	13	8	2.24	+0.32	Three Links	5.53	Yale	0.11
Pennsylvania	55.2	−4.9	3 stations	98	23	3 stations	22	[2] 3	3.49	−0.30	Center Hall	7.98	Erie	1.02
Porto Rico	76.9	−0.3	Bayamon	96	[2] 26	2 stations	57	[2] 5	3.25	−3.31	Rio Grande	8.82	Mona Island	0.24
South Carolina	68.3	−2.7	Society Hill	100	31	Caesar's Head	33	1	2.18	−1.46	Landrum	6.90	Paris Island	0.03
South Dakota	56.4	+0.6	Forestburg	104	21	Pollock	15	17	1.52	−1.45	Harveys Ranch	6.02	Castlewood	0.16
Tennessee	64.1	−3.1	Perryville	99	31	2 stations	31	26	1.98	−2.20	Hohenwold	3.79	Charleston	0.22
Texas	73.7	+0.6	Encinal	115	24	do	34	1	2.65	−1.01	Eagle Pass	12.72	Falfurrias	T.
Utah	59.2	+4.1	Hanksville	104	29	Woodruff	19	9	0.88	−0.40	Park City	3.26	12 stations	0.00
Virginia	59.8	−4.6	Danville	100	23	Burkes Garden	21	8	2.17	−1.78	Runnymede	4.07	Narrows	0.75
Washington	57.9	+3.0	Darrington	96	16	Snyder's Ranch	23	3	1.58	−0.17	Touchet Ridge	5.26	Brewster	0.09
West Virginia	56.8	−4.8	Martinsburg	100	23	Cheat Bridge	21	27	3.35	−0.84	Bayard	6.56	Upper Tract	0.70
Wisconsin	51.8	−2.9	La Crosse	98	22	Long Lake	15	8	1.22	−2.70	River Falls	2.37	Prairie du Sac	0.13
Wyoming	52.6	+3.1	Basin	96	29	Dubois	7	8	1.82	−0.20	Buffalo Ranch	4.30	Dubois	0.15

[1] For description of tables and charts, see REVIEW, January, 1925, p. 42.
[2] Other dates also.

TABLE 1.—*Climatological data for Weather Bureau stations, May, 1925*

Districts and stations	Elevation of instruments			Pressure			Temperature of the air												Precipitation			Wind									
	Barometer above sea level	Thermometer above ground	Anemometer above ground	Station, reduced to mean of 24 hours	Sea level, reduced to mean of 24 hours	Departure from normal	Mean max. + mean min. ÷ 2	Departure from normal	Maximum	Date	Mean maximum	Minimum	Date	Mean minimum	Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Total	Departure from normal	Days with 0.01, or more	Total movement	Prevailing direction	Maximum velocity: Miles per hour	Maximum velocity: Direction	Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F.	°F.	°F.	°F.	%	In.	In.		Miles.								0–10	In.	In.
New England							**53.1**	**−1.6**										**73**	**2.21**	**−1.1**										**5.7**		
Eastport	76	67	85	29.82	29.90	−.06	46.6	−1.1	70	13	54	36	2	40	29	43	40	80	1.18	−2.6	11	6,856	s.	36	e.	5	4	15	12	6.4	T.	0.0
Greenville, Me	1,070	6		28.74	29.90		47.6		77	20	58	29	7	37	36				1.82		17		se.				4	9	18		T.	0.0
Portland, Me	103	82	117	29.81	29.93	−.04	51.8	−1.5	77	17	60	39	10	44	27	46	41	69	1.24	−2.4	13	6,621	s.	30	s.	4	7	15	9	5.7	T.	0.0
Concord	288	70	79	29.60	29.91	−.07	52.8	−1.5	80	21	65	33	8	40	39				1.89	−1.4	17	2,266	w.	9	s.	1	11	11	9	4.6	0.0	0.0
Burlington	404	11	48	29.48	29.92	−.05	50.3	−6.2	77	20	60	33	23	41	33				2.65	−0.2	18	7,260	s.	38	s.	17	3	9	19	7.4	T.	0.0
Northfield	876	12	60	28.97	29.92	−.05	47.9	−4.9	77	20	60	28	10	35	41	44	40	73	2.15	−0.6	18	5,186	s.	35	sw.	1	3	12	16	6.8	0.0	0.0
Boston	125	115	188	29.79	29.93	−.05	57.4	+0.3	83	21	66	42	25	48	31	51	45	68	2.07	−1.4	11	6,914	sw.	29	w.	17	5	20	6	6.2	0.0	0.0
Nantucket	12	14	90	29.93	29.94	−.05	52.8	+0.5	69	31	59	42	2	46	24	49	46	82	2.22	−0.4	11	11,265	sw.	47	ne.	25	11	12	8	5.3	0.0	0.0
Block Island	26	11	46	29.90	29.93	−.06	53.6	+0.8	73	23	60	42	25	47	21	49	47	82	2.56	−1.2	9	10,956	sw.	42	sw.	17	15	6	10	4.8	0.0	0.0
Providence	160	215	251	29.76	29.94	−.04	56.2	−2.3	80	23	66	39	26	46	30	49	42	62	1.92	−1.5	12	7,910	w.	42	w.	17	7	19	5	5.1	0.0	0.0
Hartford	159	122	140	29.76	29.93	−.05	57.0	−0.5	82	23	68	39	8	46	34				2.36	−1.2	10		s.				11	12	8	5.3	0.0	0.0
New Haven	106	74	153	29.82	29.94	−.05	57.2	−0.7	81	23	66	41	9	48	30	50	44	65	4.07	+0.4	9	6,512	sw.	37	n.	23	9	12	10	5.0	0.0	0.0
Middle Atlantic States							**59.0**	**−3.0**										**68**	**2.03**	**−1.5**										**5.4**		
Albany	97	102	115	29.82	29.93	−.05	54.8	−4.5	80	20	65	37	9	44	32	48	42	64	2.01	−1.0	13	5,463	s.	30	s.	16	9	13	9	5.2	0.0	0.0
Binghamton	871	10	84	28.99	29.92	−.06	53.0	−4.4	82	31	65	34	25	42	38				2.50	−0.6	16	4,349	w.	26	s.	17	6	13	12	6.2	T.	0.0
New York	314	414	454	29.61	29.94	−.05	58.2	−2.4	92	23	67	40	25	50	34	51	45	65	2.43	−0.8	6	11,655	s.	64	n.	23	5	16	10	6.2	0.0	0.0
Harrisburg	374	94	104	29.57	29.97	−.01	58.4	−3.4	94	23	69	38	25	48	33	51	44	62	2.17	−1.5	13	4,925	nw.	27	sw.	23	4	15	12	6.5	0.0	0.0
Philadelphia	114	123	190	29.84	29.97	−.02	61.6	−1.3	96	23	71	42	1	52	36	54	49	68	2.36	−0.8	6	6,363	sw.	26	ne.	24	7	15	9	5.5	0.0	0.0
Reading	325	81	98	29.61	29.96		58.9		95	23	70	40	3	48	33	52	47	67	2.99	−0.4	10	4,539	sw.	22	w.	23	8	17	6	4.9	0.0	0.0
Scranton	805	111	119	29.09	29.95	−.03	55.6	−3.8	88	23	66	36	25	45	34	52	49	82	3.21	−0.2	10	5,563	sw.	39	nw.	23	7	13	11	5.8	T.	0.0
Atlantic City	52	37	172	29.90	29.96	−.02	58.0	−0.1	95	23	64	43	26	52	37	53	48	72	1.74	−1.3	7	11,287	s.	51	e.	24	11	14	6	4.8	0.0	0.0
Cape May	17	13	49	29.98	30.00	+.01	59.4	+0.8	93	23	68	43	26	51	35	54	50	75	0.49	−2.5	9	5,385	s.	35	e.	24	10	9	12	5.6	0.0	0.0
Sandy Hook	22	10	55	29.92	29.94		57.8		89	23	66	42	1	50	30	51	46	69	2.27		7	9,986	s.	54	n.	23	5	15	11	5.7	0.0	0.0
Trenton	190	159	183	29.75	29.95		59.4		94	23	70	40	6	48	35	53	48	70	2.00	−1.5	7	7,371	sw.	42	nw.	23	5	14	12	6.3	0.0	0.0
Baltimore	123	100	113	29.83	29.96	−.03	61.2	−3.2	98	23	72	40	6	51	39	53	46	60	1.86	−1.7	6	4,347	sw.	21	sw.	23	10	10	11	5.4	0.0	0.0
Washington	112	62	85	29.85	29.97	−.03	60.6	−3.1	97	23	72	38	6	49	42	53	47	63	1.67	−2.2	9	4,320	s.	27	nw.	5	12	12	7	4.8	0.0	0.0
Cape Henry	18	8	54	29.95	29.97		63.4		98	23	72	44	3	55	33	57	52	71	2.27	−1.8	12	8,789	sw.	40	nw.	24	11	13	7	5.0	0.0	0.0
Lynchburg	681	153	188	29.24	29.98	−.02	61.3	−6.0	94	23	73	37	3	50	34	54	49	66	1.34	−2.6	9	5,085	w.	32	w.	24	12	12	7	4.8	0.0	0.0
Norfolk	91	170	205	29.89	29.99	−.01	64.4	−1.8	94	23	73	44	2	55	32	56	51	66	1.72	−2.4	10	9,226	ne.	35	w.	5	12	12	7	5.0	0.0	0.0
Richmond	144	11	52	29.83	29.98	−.01	62.0	−4.5	96	23	73	38	1	51	32	55	50	68	2.15	−1.7	9	5,416	sw.	40	nw.	24	14	10	7	4.3	0.0	0.0
Wytheville	2,304	49	55	27.63	29.98	−.01	56.8	−4.6	84	23	67	31	27	46	35	51	46	72	1.61	−2.3	9	4,377	w.	24	w.	24	9	14	8	5.4	0.0	0.0
South Atlantic States							**67.8**	**−2.3**										**69**	**2.68**	**−1.1**										**4.6**		
Asheville	2,255	70	84	27.67	30.00	+.01	59.7	−2.9	86	31	71	33	3	49	33	52	48	71	2.15	−1.4	9	4,980	n.	28	n.	25	11	12	8	4.5	0.0	0.0
Charlotte	779	55	62	29.16	30.00	+.01	66.2	−2.7	96	23	77	41	1	55	31	57	51	64	1.64	−2.3	9	3,073	ne.	19	nw.	4	14	10	7	4.5	0.0	0.0
Hatteras	11	11	50	29.97	29.98	−.03	67.3	−1.4	82	31	74	53	26	61	19	62	59	76	0.72	−3.4	7	10,386	sw.	38	n.	25	17	8	6	4.1	0.0	0.0
Raleigh	376	103	110	29.59	29.99	.00	64.8	−3.7	94	23	76	43	27	54	29	57	51	67	4.11	−0.8	9	5,628	sw.	33	sw.	4	10	13	8	5.1	0.0	0.0
Wilmington	78	81	91	29.92	30.00	−.01	67.9	−2.9	90	22	78	46	27	58	30	61	57	71	3.08	−1.0	7	5,069	sw.	26	sw.	4	15	10	6	4.4	0.0	0.0
Charleston	48	11	92	29.95	30.00	−.01	71.0	−1.7	22	22	79	51	2	64	27	64	60	73	1.96	−1.5	4	7,392	sw.	34	ne.	25	12	10	9	5.2	0.0	0.0
Columbia, S. C	351	41	57	29.62	30.00	.00	69.3	−2.6	93	23	81	45	2	58	31	60	54	66	3.18	0.0	7	4,638	ne.	33	sw.	4	13	13	5	4.4	0.0	0.0
Due West	711	10	55	29.26	30.02		67.1		94	31	80	40	2	55	32				1.83		7	5,977	sw.	37	w.	4	11	13	7	4.6	0.0	0.0
Greenville, S. C	1,039	113	122	28.90	29.98		66.0	−1.2	90	23	77	40	1	55	30	57	50	62	1.75		10	4,936	e.	40	w.	4	12	14	5	4.2	0.0	0.0
Augusta	182	62	77	29.79	29.98	−.01	70.2	−2.2	95	23	82	46	3	59	32	62	57	67	2.73	−0.5	9	4,114	nw.	36	nw.	4	10	14	7	4.7	0.0	0.0
Savannah	65	150	194	29.92	29.99	−.01	71.4	−2.0	91	23	80	47	2	62	26	64	60	74	2.43	−0.6	7	7,892	sw.	36	nw.	12	18	5	8	4.2	0.0	0.0
Jacksonville	43	209	245	29.94	29.99	−.01	72.5	−2.5	89	25	80	51	2	65	21	65	61	73	4.75	+0.5	9	8,356	se.	39	ne.	14	12	8	11	5.1	0.0	0.0
Florida Peninsula							**76.6**	**−1.4**										**75**	**10.00**	**+5.8**										**5.7**		
Key West	22	10	64	29.92	29.94	−.03	78.4	−0.7	87	13	84	66	7	73	19	73	70	77	4.76	+1.4	12	7,084	se.	50	sw.	7	13	9	9	5.3	0.0	0.0
Miami	25	71	79	29.94	29.97		75.9	−2.7	87	26	82	60	3	70	19	71	68	77	18.66	+12.2	19	5,348	e.	27	w.	6	3	13	15	7.0	0.0	0.0
Tampa	35	79	87	29.93	29.96	−.03	75.6	−0.7	91	15	84	54	3	67	27	67	64	72	6.58	+3.7	10	4,227	e.	21	sw.	19	6	13	12	6.0	0.0	0.0
Titusville	44	5		29.93	29.98		73.6		91	14	82	48	3	65	34				11.10		12		e.				17	4	10	4.6	0.0	0.0
East Gulf States							**71.1**	**−1.3**										**66**	**3.06**	**−0.5**										**4.2**		
Atlanta	1,174	190	216	28.77	30.00	+.01	68.0	−1.9	91	31	77	42	1	59	24	59	53	65	2.00	−1.1	9	7,042	nw.	36	nw.	2	12	7	12	5.1	0.0	0.0
Macon	370	78	87	29.59	29.98	−.01	70.5	−1.8	95	31	82	42	2	59	34	60	54	60	1.13	−1.8	5	4,363	nw.	31	w.	11	12	12	7	4.8	0.0	0.0
Thomasville	273	49	58	29.69	29.98	−.01	73.2	−0.8	92	31	84	47	2	62	30	63	58	65	1.41	−2.6	8	3,128	ne.	16	sw.	4	9	8	14	5.8	0.0	0.0
Apalachicola	36	42	49	29.94	29.98		72.4		88	25	78	52	2	66	22	67	64	75	4.02		6	5,801	se.	27	ne.	28	17	9	5	3.4	0.0	0.0
Pensacola	56	149	185	29.92	29.98	−.01	72.0	−1.9	85	15	78	51	1	66	25	66	63	76	2.38	−0.3	5	8,278	s.	43	se.	14	14	9	8	4.3	0.0	0.0
Anniston	741	9	57	29.29	30.02	+.03	67.8	−0.6	93	22	80	37	1	55	34				3.87	+0.8	9	2,924	nw.	24	n.	24	16	11	4	3.8	0.0	0.0
Birmingham	700	11	48	29.26	30.01	+.03	69.3	−1.8	92	31	80	42	1	58	30	58	52	60	2.44	−0.6	6	4,339	n.	27	s.	9	17	9	5	3.7	0.0	0.0
Mobile	57	125	161	29.92	29.98	−.01	72.3	−2.1	89	29	81	49	1	63	29	64	60	72	4.18	+0.2	7	6,687	s.	37	sw.	10	12	12	7	4.3	0.0	0.0
Montgomery	223	100	112	29.74	29.99	.00	72.2	−1.2	93	22	83	48	1	62	29	61	55	59	1.83	−2.0	6	4,430	w.	28	nw.	24	20	6	5	3.7	0.0	0.0
Corinth	469	6					68.1		95	31	81	42	5	55	44				2.98		6		ne.				9	20	2		0.0	0.0
Meridian	375	85	93	29.59	29.98	.00	70.0	−1.3	91	30	82	43	1	59	37	61	55	62	3.76	−0.2	5	3,543	sw.	30	nw.	4	15	11	5	3.8	0.0	0.0
Vicksburg	247	65	73	29.73	30.01	+.04	72.1	−0.8	93	30	83	47	1	62	29	61	55	63	6.17	+1.9	4	4,217	se.	25	nw.	10	12	12	7	4.5	0.0	0.0
New Orleans	53	76	84	29.92	29.97	.00	74.8	−0.6	90	24	83	54	1	66	24	66	62	69	4.51	+0.6	8	4,623	s.	22	n.	13	14	12	5	3.8	0.0	0.0
West Gulf States							**73.4**	**0.0**										**67**	**2.17**	**−1.9**										**4.1**		
Shreveport	249	77	93	29.71	29.98	+.03	73.0	−0.6	92	30	84	44	1	62	32	62	56	62	1.45	−2.7	6	4,402	ne.	23	n.	24	18	8	5	3.5	0.0	0.0
Bentonville	1,303	11	44				63.7	−2.7	89	15	75	36	1	53	33				1.58		7	3,475	s.	26	s.	16	14	10	7		0.0	0.0
Fort Smith	457	79	94	29.49	29.97	+.04	68.4	−1.2	92	30	79	43	1	58	32	60	55	66	1.44	−3.5	8	5,037	e.	39	n.	23	12	8	11	5.2	0.0	0.0
Little Rock	357	136	144	29.60	29.97	+.02	69.0	−1.3	92	30	80	44	1	58	30	59	51	58	1.42	−3.7	4	5,435	s.	48	n.	13	10	12	9	4.9	0.0	0.0
Brownsville	57	53	61	29.84	29.90		77.6	−1.0	94	24	86	51	1	69	23	70	67	79	2.91		2	5,495	se.	29	n.	31	16	11	4	3.9	0.0	0.0
Corpus Christi	20	11	73	29.92	29.94	+.04	77.0	+0.8	90	24	83	45	1	71	26	71	68	78	0.06	−2.7	2	9,852	se.	37	n.	25	14	16	1	4.0	0.0	0.0
Dallas	512	109	117	29.42	29.96		73.0		94	23	83	48	1	63	27				6.54		5	5,513	s.	26	s.	15	17	8	6	3.6	0.0	0.0
Fort Worth	670	106	114	29.22	29.92	+.01	73.8	+1.5	94	23	83	49	1	64	30	62	55	58	8.11	+4.0	7	7,154	s.	30	sw.	16	11	13	7	4.8	0.0	0.0
Galveston	54	106	114	29.92	29.98	+.04	75.2	+0.4	86	25	80	53	1	71	20	68	65	74	1.37	−1.9	3	7,703	s.	31	n.	17	22	9	0	2.5	0.0	0.0
Groesbeck	461	11	56	29.47	29.94		74.4		95	13	86	44	1	62	32				0.67		4	7,310	s.	41	sw.	14	12	14	5	4.5	0.0	0.0
Houston	138	111	121	29.82	29.97		76.0	+0.5	93	24	87	47	1	65	27				1.71		6	5,077	se.	25	e.	14	16	15	0	3.5	0.0	0.0
Palestine	510	64	72	29.44	29.96	+.03	73.2	+0.5	93	23	84	45	1	62	30	62	56	62	1.21	−3.7	5	5,337	s.	30	ne.	14	9	17	5	4.7	0.0	0.0
Port Arthur	34	58	66	29.92	29.96		74.8		90	17	82	47	1	67	27	67	63	73	0.53		6	6,395	s.	44	nw.	19	17	12	2	3.2	0.0	0.0
San Antonio	693	119	132	29.20	29.92	+.02	77.2	+2.1	101	24	89	46	1	64	31	65	60	61	2.85	−0.1	5	5,879	s.	44	w.	8	10	16	5	4.6	0.0	0.0
Taylor	583	55	63	29.37	29.98	+.07	76.2	+1.1	99	24	88	46	1	64	30				1.60	−2.4	4	6,644	se.	32	sw.	8	14	9	8	4.5	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, May, 1925*—Continued

Districts and stations	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature of the air: Departure from normal	Temperature of the air: Maximum	Temperature of the air: Date	Temperature of the air: Mean maximum	Temperature of the air: Minimum	Temperature of the air: Date	Temperature of the air: Mean minimum	Temperature of the air: Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F		°F	°F.		°F	°F.	°F.	°F.	%	In.	In.		Miles.								0-10	In.	In.
Ohio Valley and Tennessee							**60.7**	**−4.2**										**62**	**2.12**	**−1.6**										**5.2**		
Chattanooga	762	189	213	29.18	29.99	.00	66.3	−2.5	93	31	77	43	3	56	29	56	49	59	1.76	−1.9	10	4,867	sw.	28	s.	10	12	14	5	4.8	0.0	0.0
Knoxville	996	102	111	28.94	29.99	.00	64.0	−3.2	91	22	74	41	1	54	31	56	50	65	2.40	−1.3	7	4,624	ne.	24	sw.	24	9	11	11	5.5	0.0	0.0
Memphis	399	76	97	29.57	29.99	+.03	68.2	−2.4	90	31	78	44	1	58	39	59	52	60	1.36	−3.0	3	4,236	n.	28	sw.	16	16	10	5	3.7	0.0	0.0
Nashville	546	168	191	29.44	30.02	+.04	64.3	−3.9	93	31	75	42	1	54	37	56	49	60	1.95	−1.6	5	6,158	w.	36	nw.	24	12	14	5	4.4	0.0	0.0
Lexington	989	193	230	28.95	30.01	+.02	59.8	−4.5	88	31	70	36	25	50	40				3.56	0.0	8	9,252	sw.	50	sw.	16	7	15	9	5.3	T.	0.0
Louisville	525	188	234	29.44	30.02	+.04	61.2	−5.4	91	22	72	35	25	51	39	52	45	60	1.08	−2.6	7	7,295	sw.	42	nw.	4	11	12	8	4.9	0.0	0.0
Evansville	431	139	175	29.55	30.02	+.05	63.2	−3.5	93	31	74	35	25	52	37	54	46	57	1.45	−2.0	8	7,335	ne.	40	sw.	16	9	19	3	4.7	0.0	0.0
Indianapolis	822	194	230	29.12	30.00	+.03	59.6	−3.3	90	22	70	34	25	49	38	50	42	56	0.94	−3.0	8	7,865	sw.	45	nw.	4	10	14	7	5.0	0.0	0.0
Royal Center	736	11	55	29.20	30.00		54.6		90	22	68	28	25	41	40				0.50		3	6,907	n.	40	w.	16	6	10	15	6.4	T.	0.0
Terre Haute	575	96	129	29.38	30.00		59.7		90	23	72	33	25	48	37	51	44	61	1.15		10	6,641	n.	39	nw.	21	8	19	4	4.9	0.0	0.0
Cincinnati	627	11	51	29.33	30.00	+.01	58.6	−4.5	89	23	70	32	25	47	39		48	66	2.05	−1.5	8	5,025	sw.	29	sw.	3	12	11	8	4.9	0.0	0.0
Columbus	822	179	222	29.12	30.00	+.02	57.4	−4.9	89	23	68	33	25	47	37	50	44	65	2.33	−1.4	7	7,439	n.	62	nw.	16	9	13	9	5.3	0.0	0.0
Dayton	899	137	173	29.03	29.99		58.0	−4.6	89	23	70	33	25	46	39	50	43	62	2.10	−1.8	8	6,603	ne.	42	sw.	16	12	12	7	4.8	0.0	0.0
Elkins	1,947	59	67	27.95	30.00	.00	54.5	−4.7	86	23	67	30	27	42	42	48	43	68	2.60	−1.4	11	4,286	nw.	36	nw.	4	8	11	12	6.2	T.	0.0
Parkersburg	638	77	84	29.36	30.01	+.02	58.8	−5.0	92	23	71	36	27	47	39	52	47	68	2.70	−0.8	12	3,920	sw.	36	nw.	21	12	8	11	5.7	T.	0.0
Pittsburgh	842	353	410	29.08	29.98	−.01	56.2	−6.2	88	23	67	33	25	46	33	49	43	63	3.42	+0.1	13	7,196	sw.	48	nw.	23	3	12	16	7.1	0.5	0.0
Lower Lake Region							**52.7**	**−4.8**										**65**	**1.66**	**−1.5**										**5.5**		
Buffalo	767	247	280	29.13	29.96	−.01	49.0	−5.6	78	16	56	31	24	42	34	45	42	82	1.24	−1.9	9	11,505	sw	52	w.	16	6	13	12	6.0	T.	0.0
Canton	448	10	61	29.42	29.90		50.0	−6.2	74	20	60	31	23	40	35				2.48	−0.4	19	8,140	sw.	39	sw.	20	13	9	9	4.9	0.7	0.0
Oswego	335	76	91		29.94	−.03	49.7	−5.5	78	16	58	33	3	41	38			71	2.05	−0.8	12		sw.	24	w.	11	11	6	14		0.5	0.0
Rochester	523	86	102	29.38	29.96	−.01	52.2	−4.9	82	16	62	32	24	42	37	45	38	62	1.20	−1.7	13	6,336	sw.	28	w.	16	6	14	11	6.0	T.	0.0
Syracuse	597	97	113	29.31	29.96	−.02	51.8	−5.5	78	31	61	33	24	42	35				2.09	−1.3	16	7,574	nw.	44	nw.	23	8	7	16	6.2	T.	0.0
Erie	714	130	166	29.19	29.96	−.02	52.4	−4.4	82	31	61	35	24	44	39	48	43	70	1.02	−2.4	11	9,415	w.	54	sw.	16	9	15	7	5.1	T.	0.0
Cleveland	762	190	201	29.16	29.98	.00	53.6	−4.3	86	31	62	36	2	45	39	47	40	62	2.24	−1.0	9	9,751	sw.	42	w.	16	6	13	12	6.1	0.0	0.0
Sandusky	629	62	70	29.31	29.99	+.01	54.8	−4.4	90	23	64	36	7	45	44				1.23	−2.0	9	6,220	sw.	32	w.	16	9	11	11	5.6	0.0	0.0
Toledo	628	208	243	29.30	29.99	+.02	55.4	−4.0	88	31	66	35	25	45	43	47	40	58	1.84	−1.4	8	9,414	sw.	44	sw.	16	15	9	7	4.7	T.	0.0
Fort Wayne	856	113	124	29.07	30.00		56.0	−4.2	90	22	68	33	25	44	42	48	40	58	0.48		6	6,222	s.	34	s.	16	11	11	9	5.2	T.	0.0
Detroit	730	218	258	29.19	29.99	+.02	54.6	−3.4	87	31	65	33	24	44	44	46	37	57	1.21	−2.1	8	7,180	sw.	29	sw.	22	9	13	9	5.4	T.	0.0
Upper Lake Region							**49.9**	**−3.2**										**64**	**1.21**	**−2.2**										**4.9**		
Alpena	609	13	92	29.30	29.97	.00	47.7	−2.8	92	31	58	29	18	37	43	42	36	66	0.44	−2.9	8	8,364	nw.	36	nw.	10	7	12	12	6.0	0.3	0.0
Escanaba	612	54	60	29.32	29.99	+.02	46.6	−3.0	91	31	56	30	17	37	38	41	35	66	0.76	−2.7	7	8,330	s.	33	n.	1	12	8	11	5.1	T.	0.0
Grand Haven	632	54	89	29.29	29.98	+.02	49.4	−5.1	81	22	58	32	24	41	33	44	38	67	1.51	−1.8	7	8,237	w.	36	sw.	23	12	13	6	4.5	T.	0.0
Grand Rapids	707	70	87	29.22	29.99	+.02	53.8	−4.2	91	22	65	33	24	42	43	46	37	56	0.98	−2.4	7	4,640	nw.	20	e.	23	13	9	9	5.3	T.	0.0
Houghton	668	62	99	29.26	29.99	+.02	47.0	−2.5	90	31	57	28	17	37	39				1.47	−1.8	11	7,577	w.	44	w.	22	15	8	8	4.4	3.0	0.0
Lansing	878	11	62	29.03	29.97		52.8	−4.1	89	31	66	29	18	39	47	46	41	67	0.70	−2.9	6	4,456	nw.	19	s.	22	13	12	6	4.7	T.	0.0
Ludington	637	60	66	29.28	29.98		47.0		75	22	54	31	8	39	28	43	39	74	1.19		8	7,802	s.	32	nw.	16	16	9	6	3.7	T.	0.0
Marquette	734	77	111	29.20	30.01	+.04	46.6	−2.4	92	31	55	31	23	38	35	40	34	64	1.46	−1.9	11	7,164	nw.	24	nw.	1	7	14	10	6.2	1.0	0.0
Port Huron	638	70	120	29.27	29.96	−.01	51.5	−3.7	87	31	62	32	18	41	34	45	38	64	0.73	−2.5	8	7,730	sw.	38	n.	23	13	10	8	4.5	T.	0.0
Saginaw	641	69	77	29.28	29.98		51.8	−5.1	89	31	63	31	18	40	38	45	38	60	1.03	−3.1	7	6,175	nw.	28	ne.	23	6	13	12	6.3	T.	0.0
Sault Sainte Marie	614	11	52	29.27	29.97	+.02	45.4	−3.6	85	31	55	27	18	35	42	40	35	70	1.62	−1.6	9	6,916	nw.	30	nw.	10	9	12	10	5.7	1.0	0.0
Chicago	823	140	310	29.11	30.00	+.04	54.7	−3.8	94	22	63	37	24	46	43	47	40	59	1.59	−1.8	8	7,648	n.	38	ne.	24	15	10	6	3.7	T.	0.0
Green Bay	617	109	141	29.30	29.96	+.01	51.3	−3.6	90	31	63	30	17	40	42	45	38	62	1.21	−2.4	9	8,601	s.	40	ne.	23	10	11	10	5.4	T.	0.0
Milwaukee	681	125	139	29.25	29.99	+.03	52.3	−1.8	91	22	62	34	6	43	46	45	39	64	1.62	−1.8	7	7,370	sw.	34	ne.	24	17	8	6	3.8	T.	0.0
Duluth	1,133	5	47	28.76	29.99	+.03	48.2	+0.9	89	31	60	25	6	37	41	41	33	60	1.79	−1.7	7	10,353	ne.	53	ne.	23	15	10	6	4.1	T.	0.0
North Dakota							**54.1**	**0.0**										**54**	**1.63**	**−0.8**										**3.7**		
Moorhead	940	50	58	28.95	29.96	+.02	53.2	−1.9	94	30	67	25	6	39	47	45	36	56	1.98	−1.0	4	5,367	n.	30	ne.	23	20	7	4	3.4	T.	0.0
Bismarck	1,674	8	57	28.21	29.99	+.07	55.6	+1.1	96	30	70	22	16	42	45	46	36	53	1.14	−1.4	5	7,514	n.	48	se.	21	24	3	4	2.8	0.0	0.0
Devils Lake	1,478	11	44	28.39	29.96	+.02	52.6	−0.1	96	30	67	18	16	38	40	44	34	52	1.27	−0.9	5	8,081	n.	38	n.	30	17	9	5	3.5	0.1	0.0
Ellendale	1,457	10	56	28.42	29.99		53.6		95	30	68	24	17	39	45				0.71		7	10,393	nw.	46	s.	22	12	13	6	4.8	T.	0.0
Grand Forks	835	12	89				52.2		93	22	67	22	6	37	43	45			2.77		5		nw.	40	se.	22	25	2	4		T.	0.0
Williston	1,878	41	48	27.98	29.95	+.02	54.9	+0.9	94	21	68	23	16	41	47	45	35	53	2.12	−0.1	6	6,257	ne.	32	n.	15	14	12	5	4.2	0.0	0.0
Upper Mississippi Valley							**58.3**	**−3.2**										**59**	**1.38**	**−2.8**										**4.3**		
Minneapolis	918	102	208	28.96	29.94		55.4	−2.3	99	22	66	32	24	44	38				2.66	−1.3	11	8,376	nw.	39	n.	19	14	10	7	4.5	0.1	0.0
St. Paul	837	236	261	29.07	29.98	+.04	54.3	−3.6	97	22	66	31	17	43	37				2.28	−1.3	10	8,742	sw.	43	sw.	31	12	14	5	4.1	0.1	0.0
La Crosse	714	11	48	29.22	29.99	+.05	55.0	−4.3	98	22	68	29	17	42	42				0.84	−2.9	7	3,506	se.	22	s.	22	12	10	9	4.8	T.	0.0
Madison	974	70	78	28.95	30.00	+.04	54.4	−3.2	90	22	65	32	24	44	43	47	40	60	0.38	−3.2	8	6,292	sw.	30	ne.	24	13	12	6	4.6	T.	0.0
Wausau	1,247	4		28.65	30.00		51.0		89	31	68	27	7	39	40				0.46		8		n.				10	10	11	5.2	T.	0.0
Charles City	1,015	10	49	28.91	29.99	+.05	55.2	−2.6	99	22	69	29	7	42	42	48	39	56	1.38	−3.6	10	4,987	nw.	26	sw.	22	16	11	4	3.5	0.0	0.0
Davenport	606	71	79	29.34	29.99	+.04	58.4	−2.9	94	22	70	36	24	46	38	50	42	57	0.98	−3.2	6	5,216	nw.	27	se.	15	20	6	5	3.5	0.0	0.0
Des Moines	861	84	97	29.08	29.98	+.05	59.4	−1.9	98	22	71	34	2	48	33	50	43	60	0.77	−3.8	9	5,733	sw.	40	sw.	22	9	13	9	4.8	0.0	0.0
Dubuque	700	81	96	29.22	29.97	+.02	56.0	−4.3	94	22	68	34	25	44	41	48	39	57	0.96	−3.4	8	4,755	nw.	24	sw.	20	12	14	5	4.7	T.	0.0
Keokuk	614	64	78	29.33	30.00	+.06	60.3	−3.5	93	22	72	35	25	49	32	52	44	59	1.28	−3.0	7	5,148	s.	32	nw.	4	15	10	6	4.1	0.0	0.0
Cairo	358	87	93	29.62	29.99	+.03	64.8	−3.6	95	22	75	39	25	54	36	55	48	59	0.86	−3.0	7	6,202	n.	40	ne.	21	10	11	10	5.2	0.0	0.0
Peoria	609	11	45	29.35	30.01	+.05	57.8	−3.9	93	22	71	30	25	45	37	50	44	62	1.53	−2.7	6	4,394	s.	25	w.	16	18	8	5	3.6	0.0	0.0
Springfield, Ill	636	10	91	29.31	29.98	+.03	61.0	−2.2	95	22	73	35	25	49	36	52	45	61	1.10	−3.4	7	5,527	w.	26	sw.	16	17	8	6	3.6	0.0	0.0
Hannibal	534	74	109	29.44	30.01	+.07	60.6	−3.0	96	21	72	34	25	50	33				2.84	−2.2	9	5,978	sw.	33	sw.	22	14	11	6	4.2	0.0	0.0
St. Louis	568	265	303	29.40	30.00	+.05	63.3	−3.6	94	22	73	38	25	54	30	53	45	58	1.48	−2.8	4	8,715	sw.	50	nw.	16	14	12	5	4.1	0.0	0.0
Missouri Valley							**60.0**	**−1.4**										**58**	**1.93**	**−2.3**										**4.8**		
Columbia, Mo	784	11	84	29.17	30.00	+.06	60.6	−3.7	92	22	71	33	25	50	36				3.56	−1.3	9	5,141	s.	38	w.	15	10	9	12	5.3	0.0	0.0
Kansas City	963	161	181	28.97	30.00	+.08	62.0	−2.8	92	22	71	39	25	53	28	54	49	66	5.49	+0.4	14	6,884	s.	35	sw.	15	12	8	11	5.0	0.0	0.0
St. Joseph	967	11	49	28.96	29.99		61.4		94	22	72	36	25	51	32	53	47	66	3.96		12	5,382	se.	29	nw.	16	14	11	6	4.0	0.0	0.0
Springfield, Mo	1,324	98	104	28.62	30.01	+.08	61.2	−3.3	88	22	71	35	25	52	32	54	48	66	2.82	−2.7	8	6,904	se.	46	n.	13	18	8	5	3.4	0.0	0.0
Iola	984	11	50	28.95	29.99	+.07	62.6	−1.9	92	21	74	36	2	51	37				1.76	−3.3	11	4,474	s.	22	nw.	3	11	8	12	5.6	0.0	0.0
Topeka	987	92	107				62.2	−2.1	94	22	73	38	1	51	33				1.92	−3.0	10	6,775	s.	36	s.	31	12	13	6	4.4	0.0	0.0
Drexel	1,299	10	54	28.61	30.00		58.6		93	20	71	29	6	46	32				1.81		9	7,519	s.	52	w.	20	10	11	10	5.3	0.0	0.0
Lincoln	1,189	11	84	28.72	29.98	+.07	60.6	−1.1	96	22	73	34	6	48	39	51	44	58	1.25	−3.0	8	7,457	s.	39	nw.	3	7	11	13	6.1	0.0	0.0
Omaha	1,105	115	122	28.81	29.99	+.07	61.2	−1.2	98	22	73	36	6	50	33	51	42	56	0.55	−4.0	10	4,837	nw.	34	n.	3	14	13	4	4.3	0.0	0.0
Valentine	2,598	47	54	27.26	29.96	+.06	57.1	+0.9	93	21	70	27	1	44	41	48	39	55	1.67	−1.7	5	7,879	s.	40	s.	31	9	16	6	4.9	T.	0.0
Sioux City	1,135	94	164	28.78	29.99	+.07	59.1	−1.3	96	20	71	31	6	48	37	50	41	57	2.19	−2.2	10	8,920	s.	44	s.	31	12	13	6	4.4	0.0	0.0
Huron	1,306	59	74	28.60	30.00	+.08	56.6	+0.2	94	20	71	27	6	42	43	47	37	51	0.40	−2.5	8	7,550	s.	36	n.	15	13	13	5	4.4	T.	0.0
Pierre	1,572	70	75	28.31	29.97	+.06	59.1	+1.1	97	21	72	30	1	46	43	48	38	51	0.63	−1.5	7	7,783	e.	46	w.	22	13	12	6	4.3	0.0	0.0
Yankton	1,233	49	57	28.68	29.99	+.07	58.3	−1.1	96	20	71	28	6	46	41				0.88	−3.0	8	5,903	w.	34	nw.	3	9	15	7	5.4	0.0	0.0

TABLE 1.—*Climatological data for Weather Bureau stations, May, 1925*—Continued

Districts and stations	Elevation of instruments: Barometer above sea level	Elevation of instruments: Thermometer above ground	Elevation of instruments: Anemometer above ground	Pressure: Station, reduced to mean of 24 hours	Pressure: Sea level, reduced to mean of 24 hours	Pressure: Departure from normal	Temperature of the air: Mean max. + mean min. ÷ 2	Temperature: Departure from normal	Temperature: Maximum	Temperature: Date	Temperature: Mean maximum	Temperature: Minimum	Temperature: Date	Temperature: Mean minimum	Temperature: Greatest daily range	Mean wet thermometer	Mean temperature of the dew point	Mean relative humidity	Precipitation: Total	Precipitation: Departure from normal	Precipitation: Days with 0.01, or more	Wind: Total movement	Wind: Prevailing direction	Wind: Maximum velocity: Miles per hour	Wind: Maximum velocity: Direction	Wind: Maximum velocity: Date	Clear days	Partly cloudy days	Cloudy days	Average cloudiness, tenths	Total snowfall	Snow, sleet, and ice on ground at end of month
	Ft.	Ft.	Ft.	In.	In.	In.	°F.	°F.	°F.		°F.	°F.		°F	°F.	°F.	°F.	%	In.	In.		Miles.								0–10	In.	In.
Northern Slope							54.8	+2.1										56	1.80	−0.6										5.1		
Billings	3,140	5					57.4		92	19	74	24	9	41	47				1.44		6		nw.				9	7	15		0.0	0.0
Havre	2,505	11	44	27.33	29.95	+.05	56.2	+2.8	91	20	71	22	10	41	45	46	37	55	0.73	−1.4	4	5,039	e.	37	sw.	28	21	8	2	2.7	0.0	0.0
Helena	4,110	87	112	25.78	29.94	+.01	54.6	+3.0	82	20	67	29	10	42	34	44	35	54	1.93	0.0	8	6,339	sw.	40	sw.	20	2	15	14	6.5	2.4	0.0
Kalispell	2,973	48	56	26.89	29.92	+.04	54.3	+2.9	78	18	67	30	10	42	38	44	33	52	0.96	−1.1	6	4,629	nw.	28	ne.	9	14	12	5	4.1	0.0	0.0
Miles City	2,371	48	55	27.46	29.99	+.08	58.0	+1.3	93	29	71	30	16	45	38	48	38	54	1.58	−0.4	8	5,373	se.	30	nw.	3	14	9	8	4.5	0.0	0.0
Rapid City	3,259	50	58	26.59	29.99	+.09	55.6	+1.6	91	21	67	32	9	44	40	47	39	56	4.18	+1.3	9	6,389	w.	36	nw.	3	7	18	6	5.3	0.0	0.0
Cheyenne	6,088	84	101	24.00	29.91	+.06	52.5	+2.2	83	20	64	26	1	40	42	43	36	60	1.56	−0.9	11	8,584	w.	44	nw.	15	5	12	14	6.7	0.0	0.0
Lander	5,372	60	68	24.63	29.92	+.04	54.8	+3.6	85	20	68	29	4	42	36	43	32	48	1.01	−1.9	8	4,324	w.	46	sw.	11	8	18	5	5.4	2.2	0.0
Sheridan	3,790	10	47	26.09	29.96		54.5		89	29	68	26	4	40	40	46	37	58	1.84		7	4,506	nw.	35	nw.	3	10	18	3	4.9	0.0	0.0
Yellowstone Park	6,241	11	48	23.88	29.95	+.04	48.1	+0.7	76	29	60	23	4	36	39	39	32	62	2.32	+0.4	15	5,564	s.	39	s.	11	5	16	10	6.2	0.7	0.0
North Platte	2,821	11	51	27.08	29.98	+.10	59.4	+0.7	97	20	72	26	1	47	46	50	42	60	1.92	−1.1	7	5,497	se.	27	n.	15	15	7	9	4.7	0.0	0.0
Middle Slope							63.5	+1.0										60	1.85	−2.0										5.1		
Denver	5,292	106	113	24.72	29.91	+.07	60.2	+4.0	90	21	72	37	1	48	35	47	36	50	0.43	−2.1	10	5,787	s.	44	ne.	3	8	17	6	5.1	0.0	0.0
Pueblo	4,685	80	86	25.26	29.88	+.05	63.3	+4.1	94	20	77	33	1	50	42	50	40	53	1.00	−0.7	6	5,345	e.	38	s.	21	8	19	4	5.3	0.0	0.0
Concordia	1,392	50	58	28.50	29.96	+.05	62.0	−1.2	93	21	74	34	1	50	39	52	45	60	2.77	−1.9	7	5,474	s.	29	s.	31	8	18	5	5.3	0.0	0.0
Dodge City	2,509	11	51	27.40	29.97	+.10	63.9	+0.4	100	21	76	33	1	52	41	54	48	66	2.18	−1.2	7	7,201	se.	37	se.	31	15	9	7	4.3	0.0	0.0
Wichita	1,358	139	158	28.54	29.96	+.06	64.5	−0.6	99	21	75	38	1	54	30	55	49	62	2.09	−2.9	6	9,240	s.	48	sw.	31	13	12	6	4.7	0.0	0.0
Broken Arrow	765	11	56	29.18	30.00		65.8		90	21	76	40	1	56	31				0.84		5	9,235	s.	62	ne.	23	9	8	14	5.9	0.0	0.0
Muskogee	652	4																														
Oklahoma City	1,214	10	47	28.69	29.96	+.07	67.0	−0.7	93	21	77	43	1	57	31	58	53	66	2.63	−3.1	8	7,089	s.	25	s.	15	8	14	9	5.2	0.0	0.0
Southern Slope							70.6	0.0										58	3.97	+1.2										4.8		
Abilene	1,738	10	52	28.14	29.91	+.04	71.4	−0.6	99	23	82	42	1	61	30	61	55	64	5.40	+1.7	9	7,228	s.	38	ne.	25	10	11	10	5.1	0.0	0.0
Amarillo	3,676	10	49	26.24	29.91	+.07	65.0	+0.9	100	20	76	39	1	54	37	55	48	64	1.94	−1.7	11	8,745	se.	39	ne.	14	10	10	11	5.6	0.0	0.0
Del Rio	944	64	71	28.92	29.89	+.04	77.2	+0.3	100	24	87	50	1	68	26				7.99	+5.6	8	7,405	se.	36	sw.	7	17	9	5	3.9	0.0	0.0
Roswell	3,566	75	85	26.30	29.84	+.02	68.9	−0.5	98	20	84	42	2	54	44	53	39	45	0.54	−0.6	5	6,374	s.	38	e.	21	11	13	7	4.4	0.0	0.0
Southern Plateau							68.9	+3.6										37	0.39	+0.1										2.9		
El Paso	3,762	110	133	26.12	29.79	+.01	73.4	+1.9	98	20	86	49	1	61	32	53	33	32	0.59	+0.2	5	7,749	e.	40	sw.	30	20	7	4	2.7	0.0	0.0
Santa Fe	7,013	38	53	23.24	29.80	−.01	59.2	+3.5	85	19	72	38	2	47	35	45	32	44	1.31	+0.2	9	4,987	se.	34	sw.	21	14	9	8	4.7	0.0	0.0
Flagstaff	6,907	10	59	23.34	29.81	+.03	53.8	+3.1	82	28	70	30	22	37	45	40		45	0.08		2	6,858	w.	38	s.	31	19	12	0		0.0	0.0
Phoenix	1,108	10	82	28.65	29.77	−.01	81.2	+6.2	106	25	97	58	11	66	41	60	44	31	0.03	0.0	2	4,197	w.	32	sw.	9	19	9	3	2.9	0.0	0.0
Yuma	141	9	54	29.64	29.78	−.01	79.2	+3.0	104	29	96	57	12	63	42	59	44	35	T.	0.0	0	4,212	w.	24	nw.	13	28	3	0	1.3	0.0	0.0
Independence	3,957	5	25	25.93	29.91	+.07	66.8	+3.8	94	26	83	37	11	51	39	47			0.02	−0.1	1		nw.				12	14	5		0.0	0.0
Middle Plateau							61.0	+5.1										42	0.93	−0.2										5.1		
Reno	4,532	74	81	25.39	29.84	−.07	58.3	+4.7	83	4	71	33	8	45	38	46	35	51	1.39	+0.6	7	5,402	w.	34	w.	30	10	12	9	5.2	0.0	0.0
Tonopah	6,090	12	20				59.4		82	25	70	32	11	49	27	44	30	40	0.05		3		nw.								0.0	0.0
Winnemucca	4,344	18	56	25.54	29.87	−.04	58.6	+4.7	85	26	74	32	8	43	42	46	35	49	0.26	−0.8	7	5,007	ne.	26	sw.	7	6	11	14	6.2	0.0	0.0
Modena	5,479	10	43	24.55	29.82	.00	58.2	+4.7	85	28	75	33	12	41	43	42	25	37	0.16	−0.7	3	8,800	sw.	51	sw.	20	14	14	3	3.7	0.0	0.0
Salt Lake City	4,360	163	203	25.53	29.83	−.03	63.3	+5.9	89	28	74	42	8	53	32	49	36	41	2.47	+0.5	11	6,093	nw.	48	w.	20	11	12	8	5.1	0.0	0.0
Grand Junction	4,602	60	68	25.30	29.82	−.01	66.8	+5.7	92	20	80	43	15	53	35	48	31	32	0.36	−0.6	5	5,347	se.	52	sw.	11	7	17	7	5.2	0.0	0.0
Northern Plateau							60.1	+3.9										47	1.68	0.0										6.0		
Baker	3,471	48	53	26.39	29.95	−.01	55.3	+3.6	80	19	68	32	9	42	42	48	44	72	1.42	−0.3	9	4,002	se.	26	se.	16	2	18	11	6.5	0.0	0.0
Boise	2,739	78	86	27.08	29.91	−.03	61.8	+4.7	87	18	74	35	8	49	36	50	40	52	0.74	−0.6	8	3,712	se.	28	se.	20	7	10	14	6.2	0.0	0.0
Lewiston	757	40	48	29.13	29.93	−.03	63.2	+3.7	90	6	77	39	3	50	44				2.37	+0.7	10	2,409	e.	23	w.	2	8	8	15	6.0	0.0	0.0
Pocatello	4,477	60	68	25.42	29.89	.00	58.3	+4.5	83	19	71	33	4	45	41	46	36	52	0.67	−1.5	9	5,548	se.	38	sw.	13	5	15	11	6.2	0.0	0.0
Spokane	1,929	101	110	27.91	29.93	−.03	59.6	+4.1	85	18	72	35	9	47	36	49	39	53	1.91	+0.3	6	4,336	s.	24	sw.	21	7	10	14	6.3	0.0	0.0
Walla Walla	991	57	65	28.86	29.92	−.04	62.6	+3.0	87	6	74	42	9	51	32	52	45	57	2.98	+1.2	9	3,448	s.	20	sw.	7	10	12	9	4.9	0.0	0.0
North Pacific Coast Region							57.0	+3.3										72	1.81	−0.7										6.4		
North Head	211	11	56	29.78	30.01	−.02	53.4	+2.5	85	15	57	45	3	49	37	50	48	85	1.40	−1.0	12	11,270	n.	54	s.	27	1	10	20	7.7	0.0	0.0
Port Angeles	29	8	53				53.0		81	16	61	37	3	45	28				0.45	−0.8	4		s.	27	nw.	21	7	14	10		0.0	0.0
Seattle	125	215	250	29.88	30.01	.00	57.8	+3.3	83	16	66	43	3	49	27	51	45	68	1.28	−0.7	5	6,141	n.	29	sw.	6	9	13	9	5.5	T.	0.0
Tacoma	194	172	201	29.78	29.98	−.04	57.8	+3.7	83	16	67	42	9	48	28				1.38	−0.8	7	5,338	n.	27	w.	28	5	16	10	6.4	0.0	0.0
Tatoosh Island	86	9	53	29.90	30.00	−.01	51.4	+1.8	63	5	55	43	3	47	15	49	47	88	3.67	−0.4	11	9,404	w.	50	s.	10	9	9	13	6.3	0.0	0.0
Yakima	1,071	5																														
Medford	1,425	4					60.8		89	5	76	39	11	46	46	51	42	59	0.95		9		nw.	22	se.	12	5	6	25		0.0	0.0
Portland, Oreg.	153	68	106	29.81	29.96	−.07	61.2	+4.3	88	5	71	45	30	51	34	53	48	67	0.74	−1.5	8	4,289	nw.	24	w.	6	5	7	19	7.1	0.0	0.0
Roseburg	510	9	57	29.43	29.98	−.05	60.2	+4.2	89	15	73	35	8	48	43	52	45	67	2.41	+0.4	14	2,402	n.	19	nw.	15	6	19	6	5.2	0.0	0.0
Middle Pacific Coast Region							59.5	+1.0										74	2.44	+1.2										5.3		
Eureka	62	73	89	29.94	30.02	−.03	53.9	+1.9	67	16	59	42	1	49	20	51	48	85	2.57	0.0	13	4,707	n.	29	sw.	31	2	11	18	7.4	0.0	0.0
Point Reyes	490	7	18	29.38	29.90		52.2	+0.6	66	2	56	44	5	48	20				4.02		11	17,228	nw.	67	nw.	6	5	8	18	7.0	0.0	0.0
Red Bluff	332	50	56	29.54	29.89	−.06	66.6	+0.3	94	25	78	48	30	55	37	56	49	59	1.53	+0.2	7	3,991	se.	23	nw.	7	15	12	4	3.8	0.0	0.0
Sacramento	69	106	117	29.84	29.91	−.03	63.9	+0.3	89	25	75	47	9	52	34	57	53	72	2.11	+1.1	8	5,693	s.	24	sw.	19	18	10	3	3.5	0.0	0.0
San Francisco	155	208	243	29.78	29.95	−.04	59.0	+2.2	83	2	65	48	8	53	29	53	50	78	4.02	+3.2	11	7,184	w.	34	w.	29	13	10	8	5.0	0.0	0.0
San Jose	141	12	110	29.80	29.95		61.2	+0.5	89	2	72	38	8	51	38				1.96	+1.3	8	5,262	nw.	34	se.	12	11	11	9	5.0	0.0	0.0
South Pacific Coast Region							63.5	+1.4										70	1.34	+0.7										4.9		
Fresno	327	89	98	29.53	29.89	−.03	68.8	+1.7	96	26	82	48	1	56	36	55	44	49	1.29	+0.7	4	5,858	nw.	32	nw.	6	18	7	6	3.3	0.0	0.0
Los Angeles	338	159	191	29.58	29.95	.00	62.8	+0.6	80	17	70	52	11	55	25	56	53	77	0.32	−0.2	2	3,952	sw.	16	w.	14	7	17	7	5.5	0.0	0.0
San Diego	87	62	70	29.85	29.94	−.01	62.3	+1.5	74	17	67	52	11	57	18	57	53	77	0.15	−0.3	4	4,791	w.	21	n.	19	9	10	12	5.8	0.0	0.0
San Luis Obispo	201	32	40	29.75	29.97	−.03	60.1	+1.9	86	1	69	45	9	51	39	53	49	76	3.58	+2.7	7	3,453	nw.	20	sw.	17	12	13	6	4.9	0.0	0.0
West Indies																																
San Juan, P. R.	82	9	54	29.89	29.98		78.8	+0.2	91	30	84	71	5	73	17				0.71	−4.0	12	8,581	e.	32	e.	12	6	23	2	4.9	0.0	0.0
Panama Canal																																
Balboa Heights	118	7	97	29.70	29.82	−.02	81.2	+0.6	94	3	88	71	19	74	19	76	75	87	6.73	−1.3	15	5,433	nw.	30	n.	18	1	16	14	7.0	0.0	0.0
Colon	36	7	97	29.79	29.83	−.02	83.0	+2.4	95	21	89	72	18	77	19	77	76	86	8.23	−4.1	19	7,352	n.	30	ne.	28	2	11	18	7.2	0.0	0.0
Alaska																																
Juneau	80	11	54				48.0		71	15	56	32	4	40	27	44	40	77	4.26		17	4,731	s.	28	se.	28	4	7	20	7.7	T.	0.0
Hawaiian Islands																																
Honolulu	38	86	100				74.1		80	31	78	68	3	70	12	66	62	68	0.61	−1.1	9	7,467	e.	32	e.	7	7	13	11	5.8	0.0	0.0

TABLE 2.—*Data furnished by the Canadian Meteorological Service, May, 1925*

Station	Altitude above mean sea level, Jan. 1, 1919	Pressure			Temperature of the air						Precipitation		
		Station reduced to mean of 24 hours	Sea level reduced to mean of 24 hours	Departure from normal	Mean max.+mean min.÷2	Departure from normal	Mean maximum	Mean minimum	Highest	Lowest	Total	Departure from normal	Total snowfall
	Feet	*In.*	*In.*	*In.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	°*F.*	*In.*	*In.*	*In.*
St. Johns, N. F.	125												
Sydney, C. B. I.	48												
Halifax, N. S.	88	29.82	29.93	−.05	49.4	+1.0	59.5	39.3	74	31	4.49	+0.23	0.0
Yarmouth, N. S.	65	29.81	29.88	−.10	46.7	−0.9	53.6	39.8	62	31	2.09	−1.71	0.0
Charlottetown, P. E. I.	38	29.84	29.88	−.08	48.3	+1.4	55.9	40.7	67	35	0.87	−2.04	0.0
Chatham, N. B.	28	29.77	29.80	−.15	47.0	−1.5	57.7	36.2	74	28	3.05	−0.16	0.0
Father Point, Que.	20	29.81	29.83	−.10	43.4	−0.6	49.6	37.2	63	26	1.80	−0.78	0.0
Quebec, Que.	296	29.56	29.88	−.06	48.8	−1.1	57.4	40.2	74	30	3.19	+0.11	0.0
Montreal, Que.	187	29.66	29.87	−.07	50.9	−3.8	59.3	42.6	77	32	4.08	+1.13	T.
Stonecliffe, Ont.	489												
Ottawa, Ont.	236	29.63	29.89	−.05	50.8	−4.1	61.0	40.7	78	30	2.69	+0.10	T.
Kingston, Ont.	285	29.60	29.91	−.05	48.7	−4.2	56.1	41.2	70	32	2.03	−0.65	0.0
Toronto, Ont.	379	29.53	29.94	−.04	50.8	−2.4	60.7	41.0	81	30	1.31	−1.73	T.
Cochrane, Ont.	930				39.1		49.6	28.6	69	17	1.30		4.2
White River, Ont.	1,244	28.60	29.93	−.02	40.7	−5.0	52.7	28.7	80	0	1.83	−0.12	10.3
Port Stanley, Ont.	592												
Southampton, Ont.	656	29.23			46.1	−4.6	55.4	36.9	72	30	1.30	−1.14	0.2
Parry Sound, Ont.	688	29.23	29.93	−.02	46.0	−5.1	56.1	35.9	69	26	1.20	−1.73	1.1
Port Arthur, Ont.	644	29.27	29.98	+.02	45.1	−0.8	55.4	34.9	83	26	1.71	−0.44	2.1
Winnipeg, Man.	760												
Minnedosa, Man.	1,690	28.16	29.98	+.02	49.5	+1.1	63.1	35.9	85	21	1.85	+0.40	0.0
Le Pas, Man.	860				45.8		59.6	32.0	79	17	1.03		0.0
Qu'Appelle, Sask.	2,115	27.70	29.93	−.01	52.3	+2.5	67.2	37.5	89	21	0.55	−1.10	0.9
Medicine Hat, Alb.	2,144	27.63	29.87	−.02	57.6	+3.5	72.0	43.3	91	23	0.22	−1.09	0.0
Moose Jaw, Sask.	1,759				53.9		70.2	37.6	93	19	0.38		0.0
Swift Current, Sask.	2,392	27.43	29.94	+.02	54.0	+3.3	69.9	38.2	87	21	0.85	−0.91	0.0
Calgary, Alb.	3,428	26.43	29.99	+.11	52.2	+3.2	67.3	37.2	85	20	0.58	−1.19	0.0
Banff, Alb.	4,521	25.38	29.93	+.05	48.4	+1.4	64.3	32.5	78	22	0.91	−1.13	0.3
Edmonton, Alb.	2,150	27.63	29.89	+.01	52.9	+2.1	66.9	39.0	87	26	1.07	−0.48	0.0
Prince Albert, Sask.	1,450	28.42	29.99	+.04	53.1	+5.5	69.4	36.9	87	24	0.40	−0.86	0.0
Battleford, Sask.	1,592	28.22	29.95	+.03	53.7	+2.7	68.5	38.9	90	24	0.62	−1.00	0.0
Kamloops, B. C.	1,262												
Victoria, B. C.	230	29.73	29.98	−.02	55.3	+2.8	63.2	47.4	84	42	0.54	−0.94	0.0
Barkerville, B. C.	4,180												
Triangle Island, B. C.	680												
Prince Rupert, B. C.	170												
Hamilton, Ber.	151	29.94	30.10	+.04	70.5	+1.1	75.9	65.1	80	57	6.60	+1.94	0.0

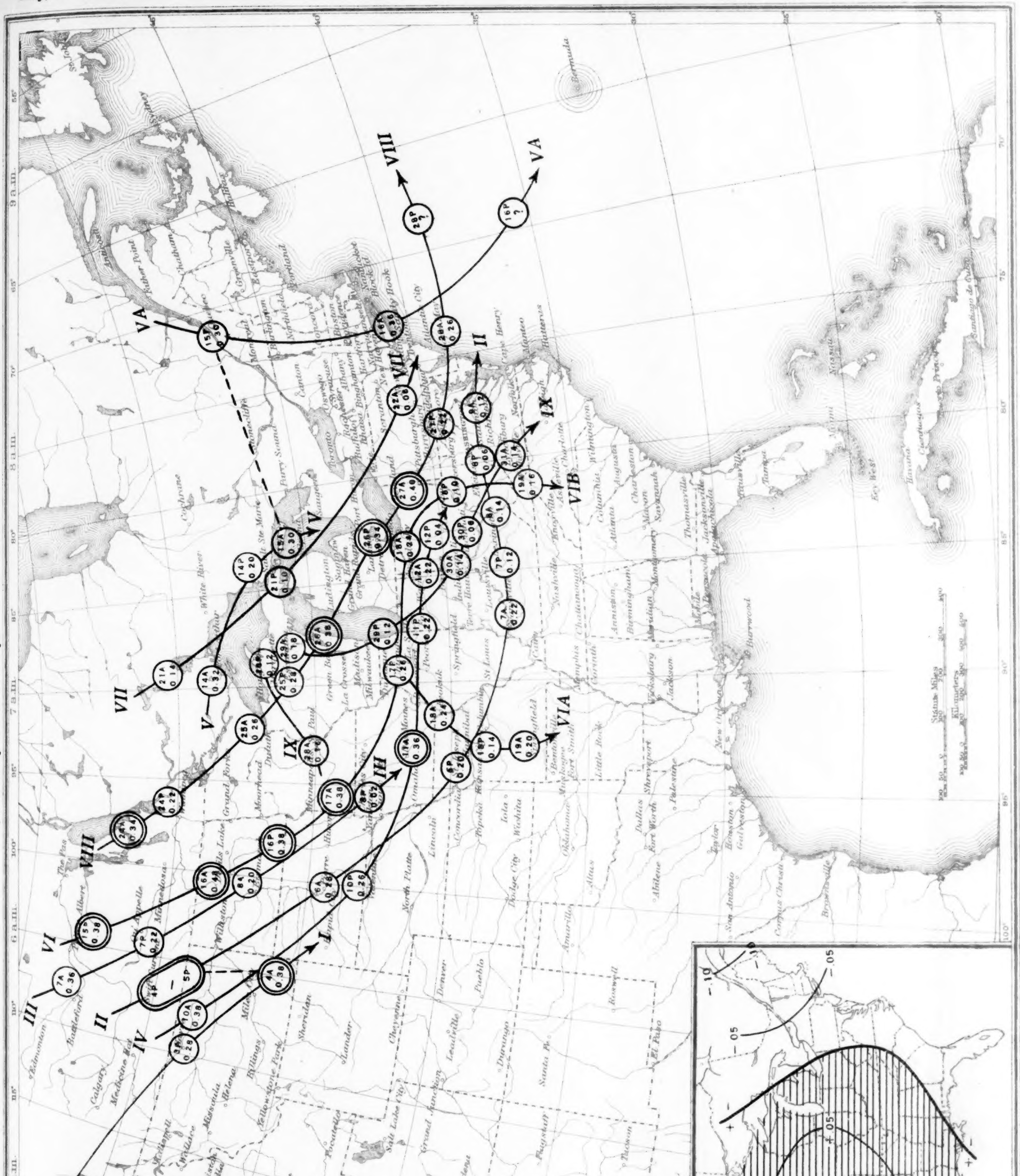


Chart I. Tracks of Centers of Anticyclones, May, 1925. (Inset) Departure of Monthly Mean Pressure from Normal
(Plotted by Wilfred P. Day)

Chart II. Tracks of Centers of Cyclones, May, 1925. (Inset) Change in Mean Pressure from Preceding Month
(Plotted by Wilfred P. Day)

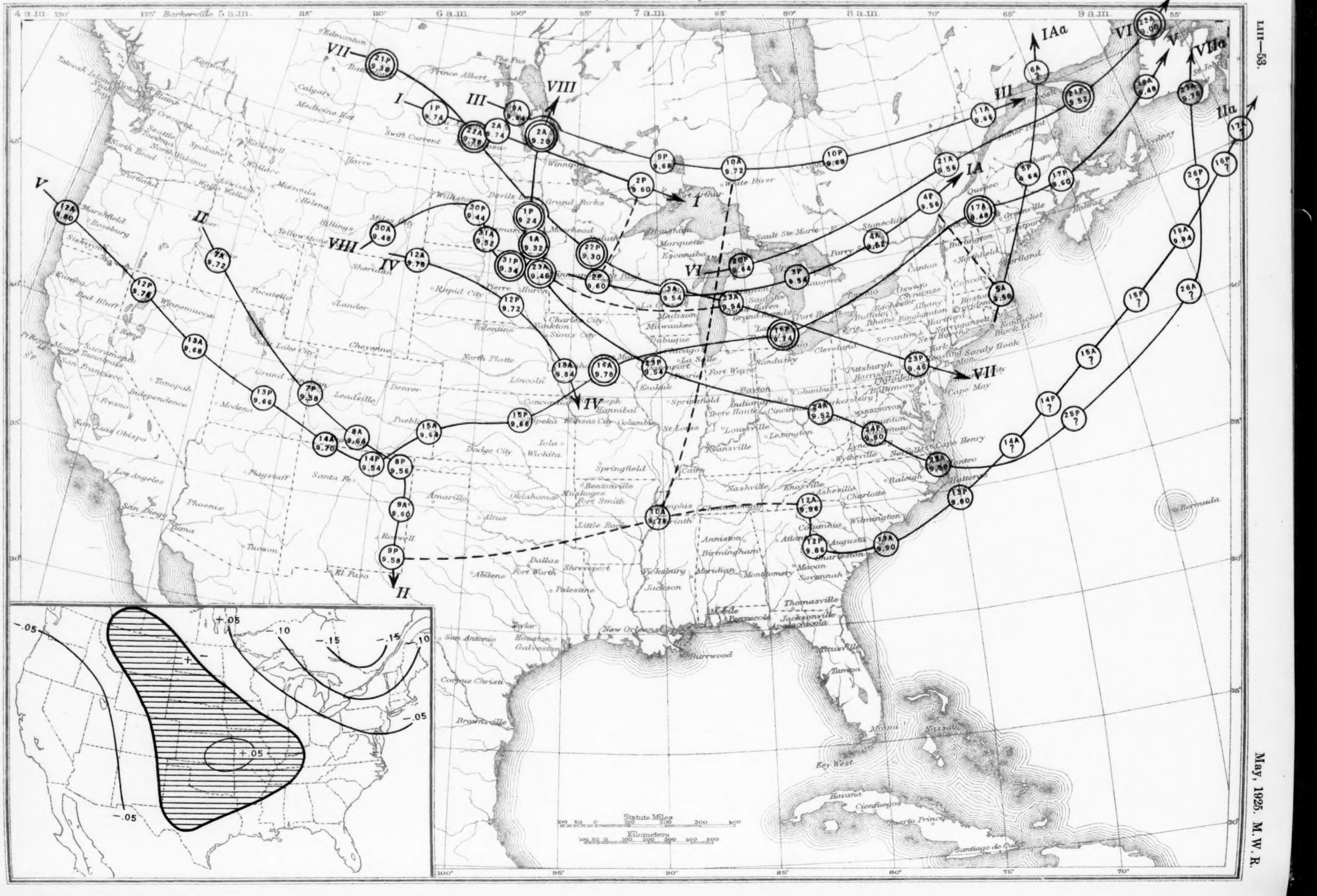
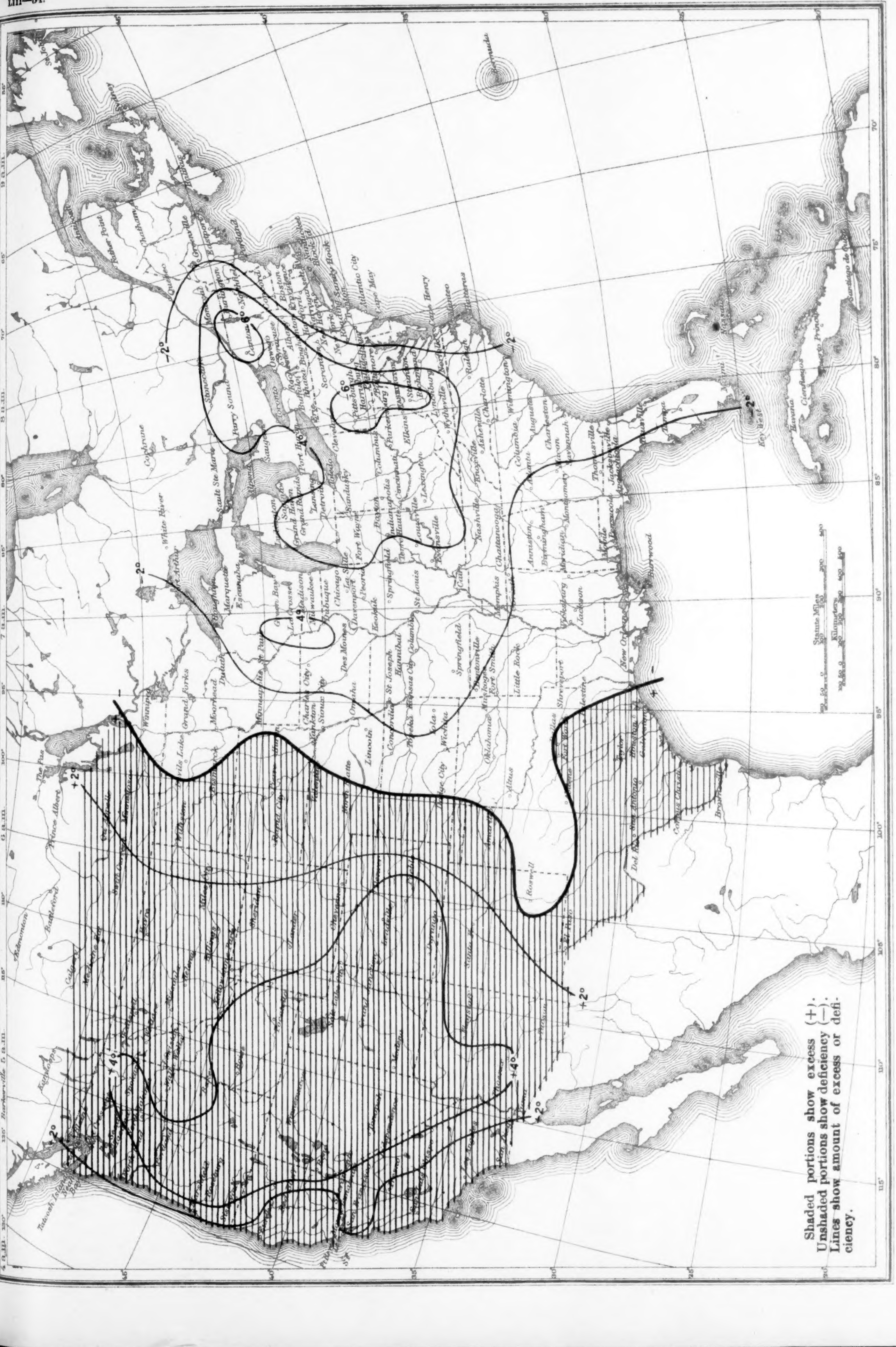


Chart III. Departure (°F.) of the Mean Temperature from the Normal, May, 1925



Shaded portions show excess (+).
Unshaded portions show deficiency (−).
Lines show amount of excess or deficiency.

Chart IV. Total Precipitation, Inches, May, 1925. (Inset) Departure of Precipitation from Normal

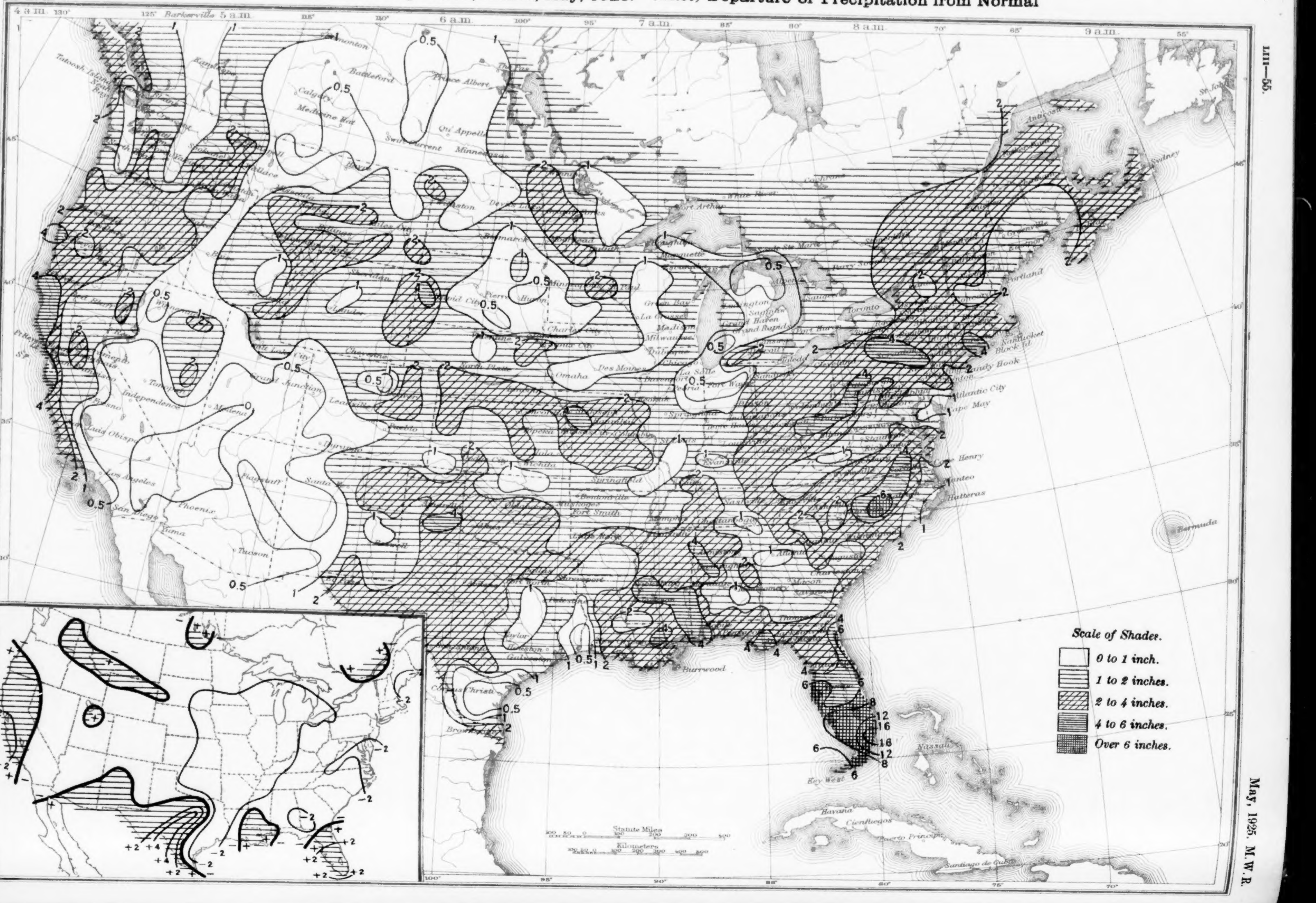


Chart V. Percentage of Clear Sky between Sunrise and Sunset, May, 1925

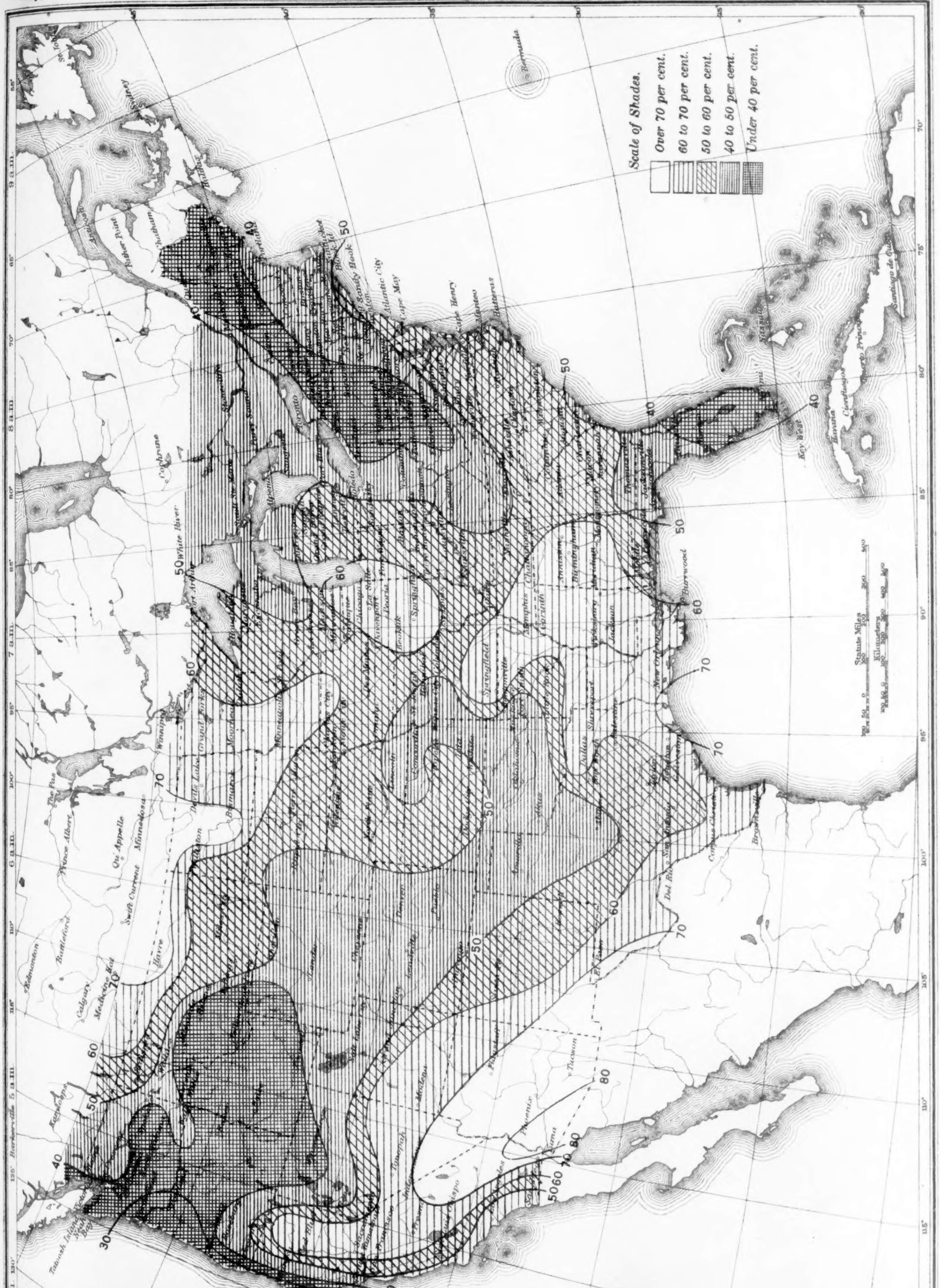


Chart V. Percentage of Clear Sky between Sunrise and Sunset, May, 1925

Chart VI. Isobars at Sea level and Isotherms at Surface; Prevailing Winds, May, 1925

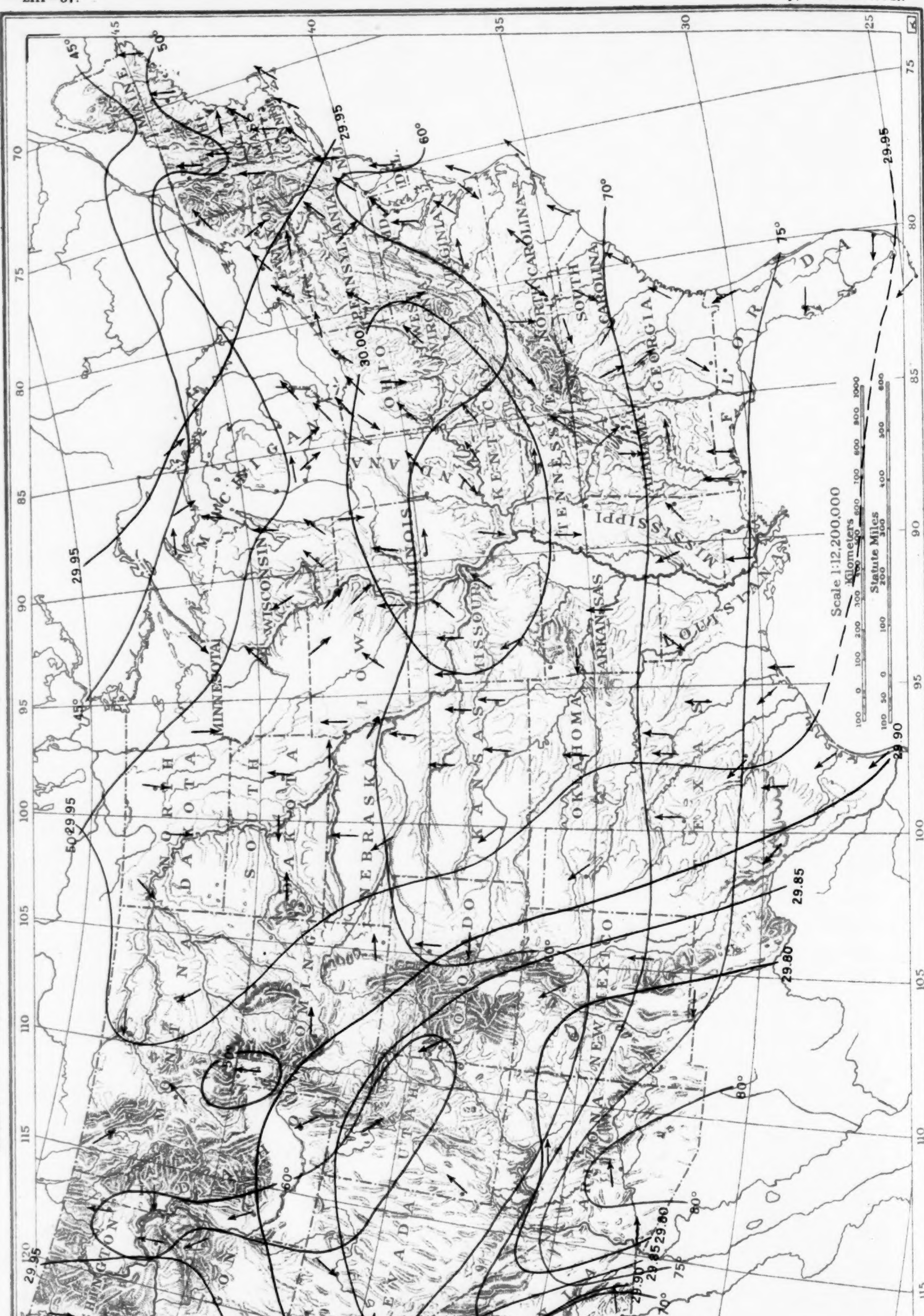


Chart VIII. Weather Map of North Atlantic Ocean, May 27, 1925
(Plotted by F. A. Young)

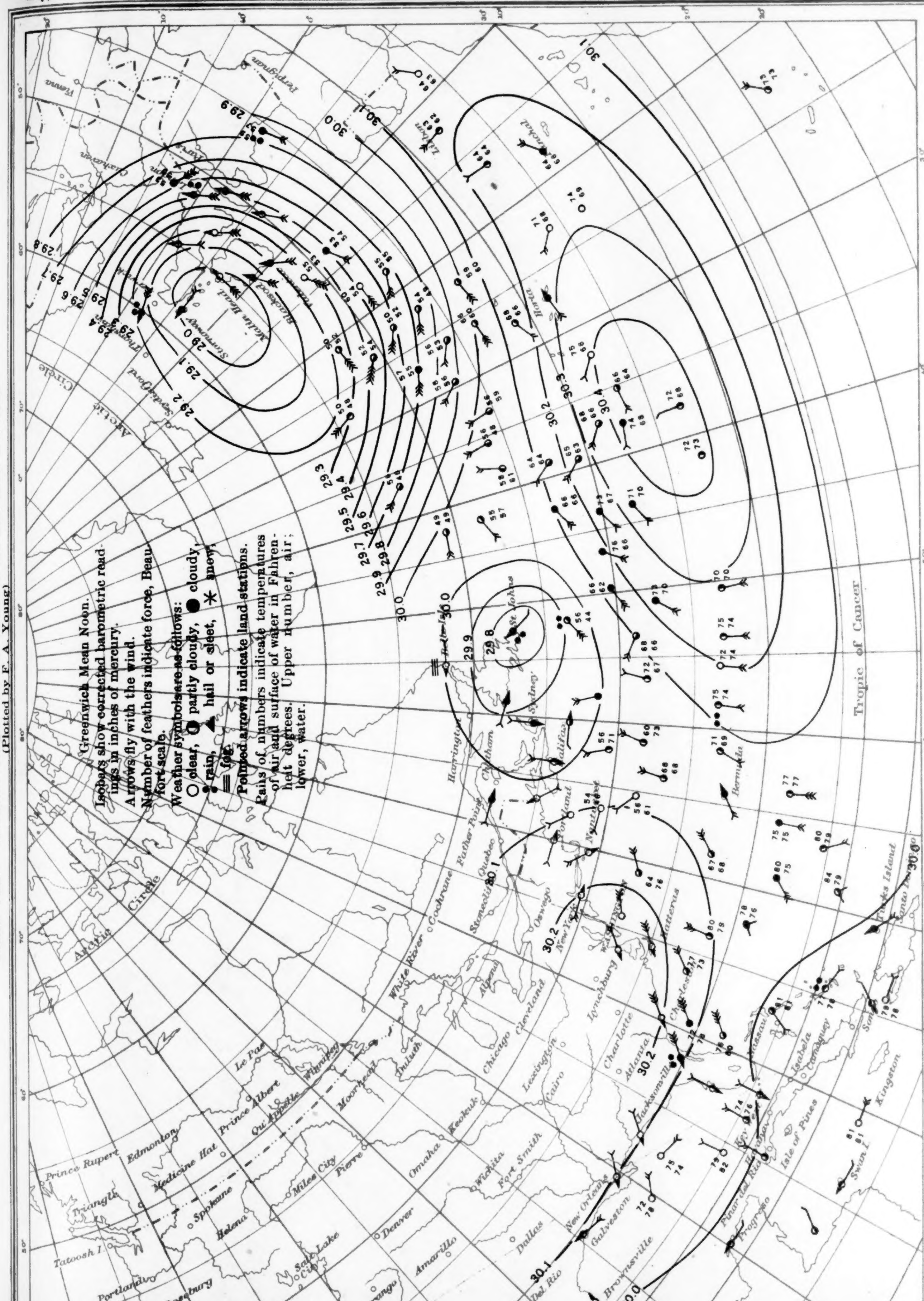


Chart IX. Weather Map of North Atlantic Ocean, May 28, 1925
(Plotted by F. A. Young)

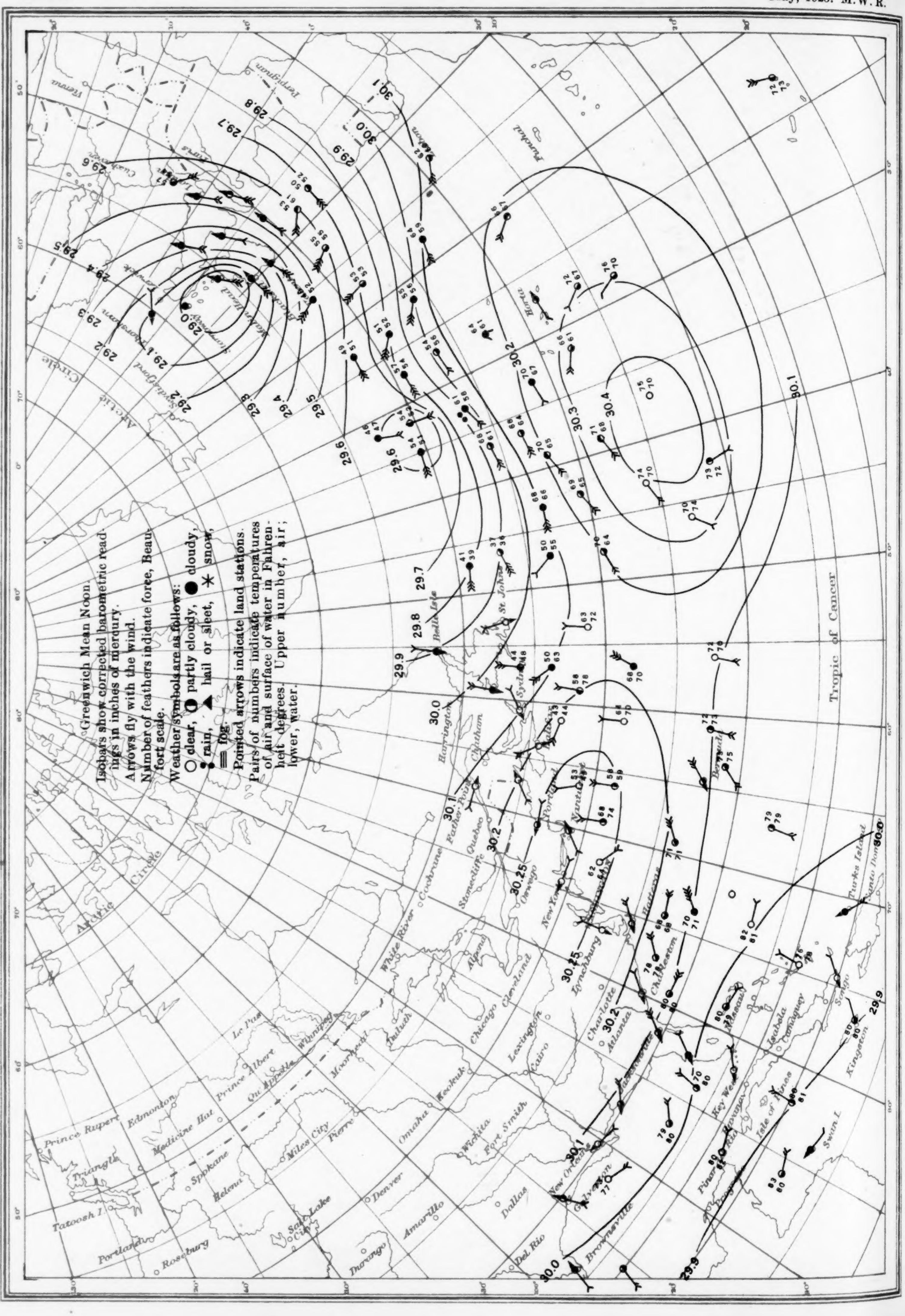


Chart X. Weather Map of North Atlantic Ocean, May 29, 1925

(Plotted by F. A. Young)

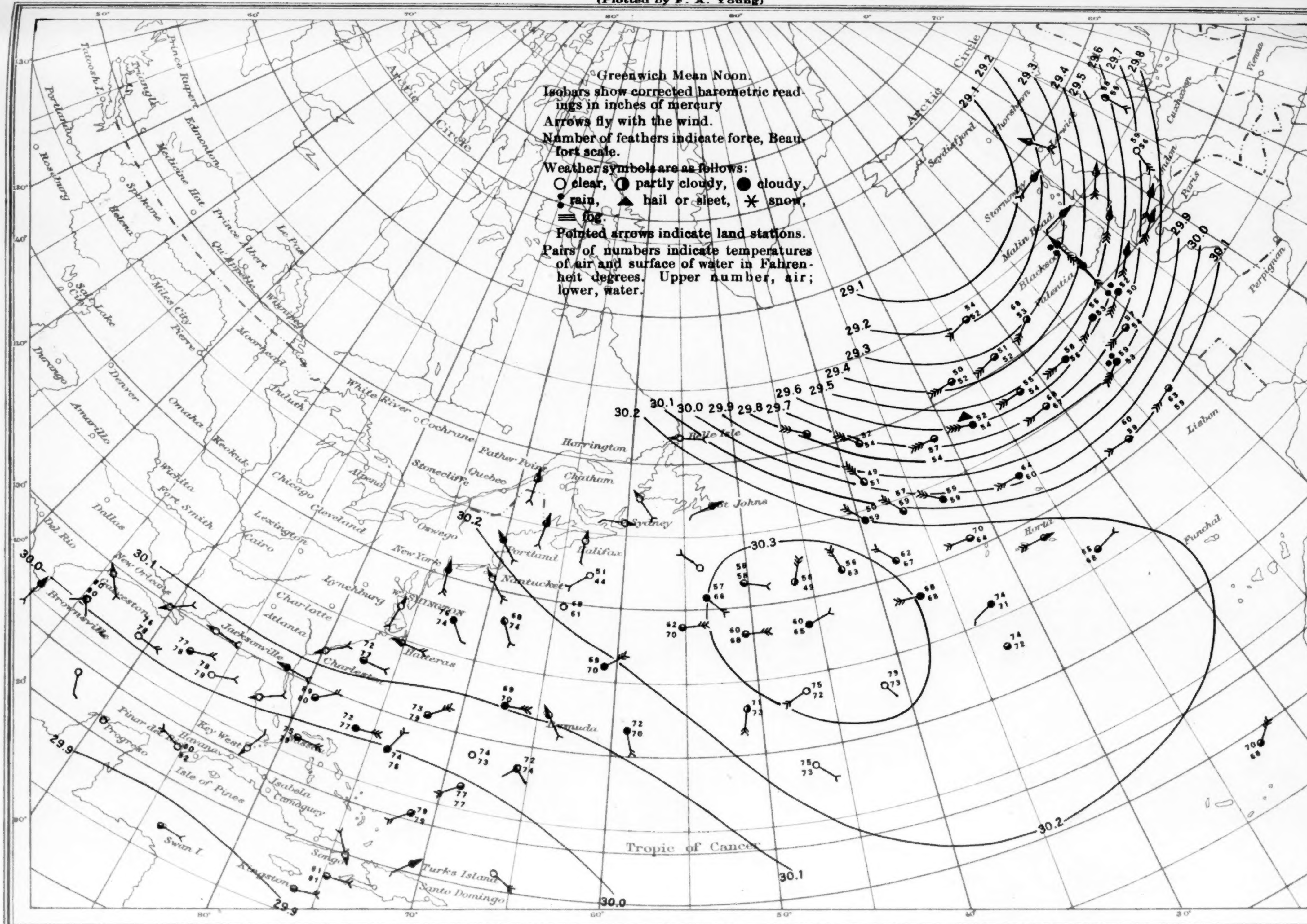


Chart XI. Weather Map of North Atlantic Ocean, May 30, 1925

(Plotted by F. A. Young)